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WATER SUPPLY AND WATER QUALITY CONTROL STUDY ARKANSAS RIVER SUBBASIN COLORADO

Federal Water Pollution Control Administration
Dallas, Texas

February 1968

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WATER SUPPLY
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WATER QUALITY CONTROL STUDY
ARKANSAS RIVER SUBBASIN
COLORADO

A Study of Needs For Municipal and Industrial Water Supply and Water Quality Control

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UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Central Region
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WATER SUPPLY

AND

WATER QUALITY CONTROL STUDY

ARKANSAS RIVER SUBBASIN

COLORADO

Abstract

A survey has been made which discloses a future need for additional municipal and industrial water supplies and a future need for storage for streamflow regulation for the purpose of water quality control. These conclusions are based on results of economic and demographic studies.

Prepared for

DEPARTMENT OF THE ARMY

Albuquerque District, Corps of Engineers

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Central Region
Dallas, Texas

FEBRUARY, 1968

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I. INTRODUCTION

Request and Authority

In a letter dated February 3, 1965, the Albuquerque District, Corps of Engineers, Albuquerque, New Mexico, requested the Public Health Service to investigate and prepare a report concerning the need for storage for municipal, industrial, and water quality control in the Arkansas River Subbasin, Colorado, above John Martin Dam.

The subsequent study was made in accordance with provisions of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.), wherein, authority is given to conduct investigations relating to the causes, control, and prevention of water pollution.

Effective December 31, 1965, Section 2 of the Water Pollution Control Act, as amended by Public Law 89-234, established the Federal Water Pollution Control Administration as an operating agency of the Department of Health, Education, and Welfare. Under Reorganization Plan No. 2 of 1966, the Administration was transferred to the Department of the Interior effective May 10, 1966. As a result of these changes, responsibility for completing this study was transferred to the Federal Water Pollution Control Administration in the U. S. Department of the Interior.

Purpose and Scope

The purpose of this study was to appraise water requirements to the year 2070 for municipal, industrial, and water quality control purposes in the Arkansas River basin above John Martin Reservoir. The results presented are based on projected economic developments and anticipated needs for water supply and stream preservation in the study area.

Acknowledgments

The assistance and cooperation of agencies and individuals who aided in the assembly of data for this report are gratefully acknowledged. Special appreciation is expressed to the following:

1. Economic Research Service of U. S. Department of Agriculture, Fort Collins, Colorado
2. Bureau of Mines, Denver, Colorado
3. Geological Survey, Denver, Colorado

4. Bureau of Reclamation, Pueblo and Denver, Colorado
5. Corps of Engineers, Albuquerque, New Mexico
6. Colorado Water Pollution Control Commission, Denver, Colorado
7. Colorado State Department of Health, Denver, Colorado
8. Colorado Division of Commerce and Development, Denver, Colorado
9. Colorado Agricultural Experiment Stations, Hydraulic Laboratory, Fort Collins, Colorado
10. Colorado School of Mines, Golden, Colorado
11. Business Research Division, University of Colorado, Boulder, Colorado
12. Colorado Office of State Planning, Denver, Colorado
13. Colorado State University, Engineering Research Institute, Fort Collins, Colorado
14. Colorado Department of Agriculture, Denver, Colorado
15. Officials of cities in the study area
16. Representatives of industry in the study area

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Findings

1. The study area comprises the 13 counties of the Arkansas River basin in Colorado above John Martin Reservoir. In 1960 the population of this area was 367,000. Approximately 265,000 or 72 percent of the population was located in or near 11 urban communities. The total 1960 rural population in the study area was 102,000.

2. Municipal and industrial water use and waste production in the study area are largely centered in the areas of Pueblo, Colorado Springs, Canon City, La Junta, Security, and Trinidad. Smaller but substantial quantities of water use and waste production occur in the vicinities of Leadville, Salida, Walsenburg, Rocky Ford, and Las Animas.

3. Estimated safe yields of principal municipal and industrial water supplies in the study area total about 265 million gallons per day (mgd). Municipal water use in the study area presently averages about 74 mgd.

4. Municipal waste discharges to study area streams are estimated to be between 40 to 50 mgd with a population equivalent (PE) of about 60,000. Biochemical oxygen demand (BOD) removal from wastes varies from 60 to 90 percent. However, the majority of the waste treatment plants provide secondary treatment with BOD removal approaching 90 percent. Principal sources of industrial water use and waste discharges are the iron and steel, food and kindred products and mining industries.

5. Adjudicated water rights for study area resources far exceed the quantity of water normally available. A large portion of the water resources of the basin are now appropriated for irrigation.

6. Acid mine drainage, largely attributed to abandoned mines, is evident in the area of Leadville. Noticeable concentrations of heavy metals potentially harmful to the stream and its environment have been observed in California Gulch, tributary to the Arkansas River near Leadville and in the

river itself immediately below this point. Also, acids are released from exposed mineral deposits at the head of the South Fork of Lake Creek frequently depressing the pH of the water below 5.0.

7. Severe mineral pollution of the Arkansas River and tributaries below Pueblo results from the return of salt laden irrigation water to the streams. Return flows frequently raise the dissolved solids concentration above 2,000 mg/l in the Arkansas River.

Conclusions

1. Authorized and presently developed municipal and industrial, and rural water supplies will be adequate to meet projected needs through the year 1990.

2. Optimum development of the water resources of the study area will eventually require that the better quality water be used to satisfy municipal and industrial water needs and that treated municipal and industrial wastes be used to make up deficiencies in irrigation water needs.

3. Study area municipal, industrial and rural water requirements are projected to be 728.6 million gallons per day by the year 2070.

4. Water from the Arkansas River and tributaries above Pueblo could satisfy anticipated study area municipal and industrial water needs through the year 2040, thereafter, additional importation of water or more intensive renovation and reuse will be required for further development.

5. If current irrigation practices persist with resultant present levels of mineral pollution, water resources in the study area would not be adequate for maintenance of desirable mineral quality in the Arkansas River below Pueblo by storage and streamflow regulation.

6. Throughout the study period (1970-2020), provision of adequate waste treatment considered to be

well operated secondary treatment achieving at least 90 percent removal of BOD, will be sufficient to maintain acceptable dissolved oxygen concentrations in study area streams, except for Fountain Creek below Colorado Springs and the Arkansas River below Pueblo.

7. To protect the water quality in Fountain Creek, advanced waste treatment facilities (facilities that will remove more than 90 percent of the BOD of the wastes) will be needed as well as storage to provide water for supplementing streamflow.

8. With treatment facilities capable of removing 93 percent of the BOD from wastes produced, the supplemental flow required to maintain acceptable dissolved oxygen concentrations in Fountain Creek is about 21,900 acre-feet per year in 2020 and 50,400 acre-feet per year in 2070. The combined yields (45,800 acre-feet per year) of Ute Pass and Fountain Creek Reservoirs would satisfy these needs through the year 2060.

9. With treatment facilities capable of removing 90 percent of the BOD from wastes produced, the supplemental flow required to maintain acceptable dissolved oxygen concentrations in the Arkansas River below Pueblo is about 85,200 acre-feet per year in 2070. Releases from Pueblo Reservoir will provide adequate streamflow through 2030. The combined yields (92,100 acre-feet per year) of Pleasant View, Welton, Apishapa, Timpas, and Adobe Reservoirs would satisfy these needs through the terminal year (2070) of this study.

10. Maximum use of flow regulation by construction of reservoirs and release of stored waters would likely provide the most economical method for water quality control in both Fountain Creek and the Arkansas River below Pueblo.

11. While appropriation of water for storage to be used <u>exclusively</u> for quality control in study area streams is not considered possible due to the scarcity of water resources, it does not appear

impossible to develop flow regulating facilities that would provide supplemental flows where required for quality control through dual use of the available resources. Studies should be initiated in cooperation with state agencies to develop a comprehensive plan for regulation of flow throughout the basin to gain optimum use of the limited resources available and to develop the legal base necessary for implementation of the plan.

III. PROJECT DESCRIPTION

The tentative plan of improvement for the Arkansas River subbasin above John Martin Dam presently under study by the Corps of Engineers does not include reservoir construction. Requests for conservation storage in multiple-purpose reservoir projects have not been received from local or State interests, and single-purpose reservoir projects for flood control on major tributaries proved to be economically infeasible during project formulation studies.

The tentative plan consists of channel improvement on the main stem of the Arkansas River from Brewster to Florence, and from Pueblo to the vicinity of Las Animas, a total distance of 82 miles. The plan would include local flood protection projects on the Arkansas River and tributaries at Cotopaxi, Florence, Portland, Pueblo, La Junta, and Rocky Ford.

Channel improvement from Pueblo to Las Animas will include construction of a low-flow channel to confine the flow during periods of low runoff. Landside drains would be provided to intercept interior runoff and lower the ground water table in the immediate area. Eighteen riverbed areas that would be cut off by channel straightening will be developed for recreation, and fish and wildlife enhancement.

IV. STUDY AREA DESCRIPTION

Location and Boundaries

As shown on figure III-1, the study area encompasses the Arkansas River drainage basin above John Martin Reservoir in southeastern Colorado, and includes 13 counties lying partially within or bordering the basin. The area approximates the southeast quarter of the State of Colorado. The study area was divided into the three subareas shown on figure III-1. They are as follows: Area I - Huerfano, Custer, Fremont, Chaffee, Lake, Park, and Teller Counties; Area II - Pueblo and El Paso Counties; Area III - Las Animas, Otero, Crowley, and Bent Counties. Area I, in essence, is the mountainous area; Area II is the metropolitan areas, and Area III is the plains or lower valley area.

Geography and Topography

The Arkansas River basin in Colorado can best be described as a Great Plains area bounded on the west by the eastern face of the Rocky Mountains, east of which is a belt of foothills running generally north and south. Originating in the snowcapped mountains of Lake County, the river parallels the Continental Divide for a distance of 70 miles, and then turns eastward flowing through a relatively narrow canyon until it emerges through the deep Royal Gorge at Canon City. From Canon City to Pueblo, the river flows through a narrow valley flanked by foothills. Below Pueblo, the river valley widens appreciably and traverses the high plains area of southeastern Colorado. Along the Arkansas River and most of its tributaries, the lands occur as river bottom land, terraces or benches, and alluvial fans. The uplands are residual soils derived from shale limestone or sandstone, except in some areas where alluvial outwash overlies the residual soil.

Types of vegetation are numerous and vary from alpine type flora around mountain peaks to various species of grass and cacti in the lower regions. At the lower elevations, pinon pine, juniper, scrub oak, and brush occur frequently along rocky ridges and some of the rugged canyons while cottonwood trees, willows, and various types of brush are found in the flatter areas along the many water courses.

The elevation of the study area ranges from over 14,000 feet in the mountainous area to about 4,000 feet at the John Martin Reservoir. From the foot of the mountains to Pueblo, the average fall of the Arkansas Valley is about 18 feet per mile, while downstream from Pueblo, it averages 7½ feet per mile. Principal tributaries entering from the north side of the river are: Oil Creek, Beaver Creek, Fountain Creek, Chico Creek, Horse Creek, and Adobe Creek.

The larger south side streams are the St. Charles River, Huerfano River, Apishapa River, and Purgatoire River.

Climate

The study area has two general types of climatic conditions. From the John Martin Reservoir to Canon City near the foot of the Rocky Mountains, the climate is semi-arid. The mean annual temperature in this area is 52° F., varying from an average of 29° F. in January to a mean of 79° F. in July. Extreme temperatures from minus 40° F. to 114° F. have been recorded in the area. 1/ In the mountains, the climate varies from arid to subhumid within relatively short distances. The summers are cool and the winters long and severe.

Much of the total precipitation at high elevations is in the form of snow. Runoff from this snowfall is a maximum in late spring and early summer months and constitutes most of the dependable water supply from downstream areas for municipal, industrial, irrigation, and other beneficial uses. Average annual precipitation in the basin varies from about 18 inches at Leadville to 14 inches at Pueblo, and 16 inches near the Colorado-Kansas border. 2/ Most of the precipitation falls during the growing season but is considered inadequate 2/ for successful crop production. The average growing season ranges from 32 days near Leadville to 167 days near the lower end of the study area.

Principal Communities and Industries

The study area is sparsely population and predominately rural in character except in and around the Pueblo and Colorado Springs metropolitan areas. Outside of these areas there were only four towns with 1960 populations in excess of 5,000. 3/ A list of principal study area communities is presented in table IV-1 by county and stream location.

With a large diversified steel plant on the southern outskirts of the city, and many manufacturing companies oriented to the primary metals, the city of Pueblo is considered the manufacturing hub of the region. A few miles west of the city in Fremont County are several other manufacturing concerns including a major producer of bulk cement, a manufacturer of gypsum wallboard, and one of the Nations largest suppliers of "scientific" toy rocket engines. Long an important railhead for transhipment of precious metals, Pueblo is the transportation center of the study area. The city is also the home of a U.S. Army Ordinance Depot, the Colorado State Hospital, and the State Fair.

Colorado Springs, best known as a tourist center, is becoming important as an electronic and industry research complex. The U.S. Air Force Academy is located on the outskirts of the city.

Table IV-1

Principal Study Area Communities

County	Town	1960 Population	Stream Location	Approx. (River Mile)
Lake	Climax	1,609	East. Fk. Ark. River	(1,459)
	Leadville	4,008	Arkansas River	(1444)
Chaffee	Buena Vista	1,806	Arkansas River	(1,409)
	Salida	4,560	Arkansas River	(1,385)
Fremont	Canon City	11,979 1/	Arkansas River	(1,331)
	Florence	2,821	Arkansas River	(1,325)
Pueblo	Pueblo	103,336 2/	Arkansas River	(1,290)
El Paso	Colorado Springs	100,220 2/	Fountain Creek	(49)
	Security	9,017	Fountain Creek	(35)
Huerfano	Walsenburg	5,071	Cucharas River	(28)
Otero	Fowler	1,240	Arkansas River	(1,234)
	Rocky Ford	4,929	Arkansas River	(1,215)
	La Junta	8,026	Arkansas River	(1,198)
Crowley	Ordway	1,254	(near) Arkansas River	(1,220)
Bent	Las Animas	3,402	Arkansas River	(1,177)
Las Animas	Trinidad	10,691	Purgatoire River	(157)

1/ Includes East Canon City and Lincoln Park.
2/ Includes Urban Fringe Areas.

While manufacturing is well established in the study area, principal industrial activities of the area are centered around agriculture and mining. Irrigation farming is widespread in the valleys of the Arkansas River and its tributary streams. Dryland farming is practiced on the more remote unirrigable lands of the high plains. Livestock raising and dairy farming are carried on in conjunction with other farming. Principal crops include grains (chiefly wheat, sorghums, and field beans), sugar beets, forage, fruit, and truck crops.

Mining, though less extensive than years past, is still a major activity. Formerly an important supplier of gold, silver, copper, and lead, the study area now produces molybdenum (used in the manufacture of steel), beryllium (a glamour metal used in rocket construction), uranium, vanadium, thorium, coal, and a number of other useful minerals.

The tourist industry is a major industry in this area. Trout fishing, pheasant and duck hunting, big game hunting, winter skiing, and many other forms of recreation are available in the study area and are drawing an increasing number of tourists to the area. Many people maintain seasonal homes for these uses.

V. WATER RESOURCES OF THE STUDY AREA

General

The economy of the study area is closely bound to its natural resources. Of these resources none is considered more important or vital to the welfare of the study area, its people, industries, and the development of its other resources than water supply. The importance attached to development of water supplies is indicated by the active work of numerous local, State, and Federal water resource agencies in the area.

The Arkansas River, fed largely by melting snows at its head in the Rocky Mountains and transbasin diversions, is the hydrologic artery of the study area. It is the principal source of water for municipal and industrial water supplies, irrigation, livestock watering, fishing, and other recreational activities.

The direct flow rights of the watercourse and all of its tributaries are greatly over appropriated.

The average flow of the river as it emerges from the mountains is about 700 cubic feet per second (cfs) as compared with total adjudicated direct flow rights downstream to the State line of over 7,000 cfs. [4/] Tributary over appropriations are even greater.

Flow of the river and its tributaries is used and reused many times before it reaches the Colorado State line. Only the most senior water rights (dating back before the turn of the century in most cases) can divert reasonably adequate supplies of river water, while junior rights can be supplied only at short and intermittent intervals.

On May 1, 1957, the Colorado Legislature enacted a ground water law which provides control over ". . . any water not visible on the surface of the ground under natural conditions."* Under terms of the law, all ground water users were required to register existing wells with the State Engineer. New wells cannot be drilled or the amount of water pumped from existing wells increased without a permit. The State Engineer, Colorado Water Conservation Board, and the State Geological Survey are presently making ground water studies of southeastern Colorado (which includes the study area) to determine ground water yields and effects of withdrawals on surface water and vice versa.

*Colorado Revised Statutes, Sections, 147-19-1 to 147-19-15.

Quantity of Water Available

Ground Water

There are three major aquifers in the Arkansas River basin in Colorado. These include: The valley fill in the valleys of the Arkansas River and its major tributaries, the Ogallala formation which is a superficial deposit of unconsolidated materials underlying the High Plains, and the Dakota sandstone which is a bedrock formation underlying the major portion of the Arkansas River basin in Colorado east of the foothills.

The valley fill is the most productive aquifer in the Arkansas River basin in Colorado. It consists largely of saturated sand and gravel and will yield water freely to wells. Yields of large capacity wells in the valley fill range from a few hundred gallons per minute to nearly 3,000 gallons per minute (gpm), average yield is about 600 gpm. The aquifer is hydraulically connected with the river and ground water and surface water constitute a common supply. The usable ground water in storage in the aquifer from Pueblo to the State line is about 1 million acre-feet. 5/

The Ogallala formation occurs at only a few locations in the study area, in parts of El Paso, Pueblo, and Crowley Counties. Much of the formation in this area is largely drained of water although in most places there is enough water for domestic and stock uses, and in a few places enough for irrigation.

The Dakota sandstone is a dependable source of domestic and stock supplies throughout a large part of the Arkansas River basin in Colorado. The formation underlies almost all of the lower half of the study area. Large capacity wells have been developed in the formation with yields ranging from a few hundred gallons a minute to more than 3,000 gpm. A number of deep wells supply water from the formation in eastern Fremont County.

Today approximately 1,400 large-capacity wells are pumped in the Arkansas River basin between Pueblo and the State line, nearly all of which are below irrigation canals and are used to supplement canal deliveries. Development of the ground water reservoir has resulted in increased beneficial use of water by supplying late season needs in all years as well as major needs during low-runoff years. 6/ Calculated 1964 pumpage for all uses in the study area was approximately 665,000 acre-feet. 7/

A summary of principal municipal and industrial ground water supplies in the study area is shown in table V-1.

Table V-1

Principal Municipal and Industrial Ground Water Supplies in the Study Area

County	Municipality Served	No. Wells	Yield (mgd)
Chaffee	Buena Vista	2	1.3 a/
	Salida	4	3.0 a/
Fremont	Florence	2	1.0 b/
Pueblo	Pueblo	6	6.0 c/
El Paso	Security	14	7.2
Otero	Fowler	5	4.0 b/ d/
	Rocky Ford	2	2.3
	La Junta	8	10.0
Crowley	Ordway	3	1.2 b/
	Sugar City	4	1.6 b/
Bent	Las Animas	4	3.4
			41.0

a/ Includes infiltration galley.
b/ Estimate.
c/ Non-potable use.
d/ Includes several springs.

Source: See table VII-1.

Surface Water

Since measurements of streamflow at points on the main stem of the Arkansas River in Colorado have been necessary for the administration of water rights for diversion along the river, gaging stations have long been maintained and operated at various locations between the headwaters of the river and the Colorado - Kansas State line. An analysis of streamflow on the Arkansas River main stem is shown on figure A-1 in Appendix A.

Streamflow at Canon City which has averaged about 700 cfs over the past 76 years, represents the major contribution of the mountainous headwaters section of the river. This flow is largely composed of melting snows and transmountain diversions which have been made throughout most of the period-of-record. Streamflow at Canon City receives some regulation by existing upstream tributary impoundments and is the amount remaining in the river after the consumptive use

incident to the irrigation of some 47,000 acres of land above Canon City located principally on tributaries.

Between Canon City and the State line, the river provides water for the irrigation of about 400,000 acres 7/ of land supplied by diversions from the main stem, and water for use at Pueblo for municipal and industrial water supply purposes. Average annual diversions below Canon City for the period 1955 to 1964 totaled 1,578,384 acre-feet. 7/ Intervening tributaries furnish water supplies to lands irrigated from them, and their discharges reaching the main stem are significant only during peak runoff periods or immediately following summer rain storms.

Streamflow in the study area portion of the Arkansas River and its tributaries fluctuates widely. During the 76-year period of record at Canon City, a maximum discharge of 19,000 cubic feet per second (cfs) was recorded on August 2, 1921, and a minimum of 69 cfs on May 13, 1959. 7/

Although limited in some instances, streamflow data are available for the watersheds within which potential reservoirs, discussed later in the report, are located. The salient points of the available data are compiled in table V-2. Flow duration curves constructed from these data are shown by figure A-2, Appendix A.

Table V-2

Streamflow Data - Selected Watersheds

Watershed or Tributary	Project(s)	Gaging Station Name & Stream Mile	Years of Record	Flow - cfs Max. Avg. Min.
Fountain Creek	Ute Pass	Manitou 55 c/	(7 months)	122 - 4
	--	Fountain 35 a/	16	22,100 54.2 0
	Fountain Creek	Pueblo 1.6	27	17,800 49.5 0
St. Charles River	Pleasant View	Pueblo 5.0	12	17,600 39.2 0
Huerfano River	Welton	Undercliffe 20 a/	25	16,800 37.5 0
		La Veta b/	30	444 24.7 2.0
Apishapa River	Apishapa	Fowler 5.4	28	33,000 34.4 0
Timpas Creek	Timpas	Rocky Ford 9.0	15	11,200 50.3 0
Adobe Creek	Adobe	-- 15 a/	--	2,000 c/ 3.0 0
Purgatoire River	Purgatoire	Las Animas 4.5	25	70,000 129.0 0
		Trinidad 156.0	55	28,000 88.6 0

a/ Estimate.
b/ Located on Cucharas River about 15 miles above Walsenburg.
c/ Estimate based on runoff characteristics of adjoining areas.

Source: Geological Survey 8/, and Colorado Division of Commerce and Development 7/

Thirteen reservoirs with storage capacities in exesss of 5,000 acre-feet are now located in the study area. These are shown on figures III-1 and IX-1 and in table V-3. Only one reservoir, the Corps of Engineers John Martin Reservoir on the Arkansas River near the Colorado - Kansas State line exceeds 100,000 acre-feet storage capacity.

Study area surface water resources are presently supplemented by nine transbasin diversion projects with total diversions averaging about 50,000 acre-feet per year. See table V-4 and figure III-1. In addition, the city of Colorado Springs in joint venture with the city of Aurora (outside the study area) has under construction the Homestake Reservoir project, a transmountain diversion project, (figure V-1) which will increase the city's water supply by about 33 mgd.

The study area's water resources could be expanded substantially by construction of the four authorized water supply projects shown in table V-5.

The proposed Trinidad project would be constructed by the Corps of Engineers and provide supplemental water supply for an irrigated area of 19,700 acres below Trinidad, and possible domestic and industrial uses.

Sugar Loaf and Twin Lakes enlargements, and Pueblo Reservoir are part of the Fryingpan-Arkansas Project of the Bureau of Reclamation. The project as proposed and delineated on figure V-1 will provide additional conservation and regulation of the native waters of the Arkansas River and will import approximately 69,100 acre-feet annually from the Colorado River watershed. The project water supply will be utilized to supplement the present irrigation and municipal supplies and for the generation of hydroelectric energy. It will provide about 20,500 acre-feet annually for municipal and industrial purposes and by multiple cycles of use, approximately 190,000 acre-feet annually of new and return flow water will be made available to supplement the present supply of irrigation water during the growing season.

Table V-3

Existing Reservoirs in the study Area [a]

Reservoir	Location	Ownership	Usable Conservation Storage (ac.-ft.)	Total Storage Capacity (ac.-ft.)
Sugar Loaf	Lake Fork	Private	17,370	17,370
Twin Lakes	Lake Creek	Private	54,900	112,500
Clear Creek	Clear Creek	Private	11,440	11,440
Cucharas	Cucharas River	Private	21,000	40,210
Horse Creek	Horse Creek (Offstream)	Private	25,000	29,000
Adobe Creek	Adobe Creek (Offstream)	Private	64,900	71,000
Model	Purgatoire River (Offstream)	Private	6,200	20,350 [b]
John Martin	Arkansas River	Corps	363,945	631,120
Lake Meredith	Arkansas River (Offstream)	Private	26,000	26,000
Lake Henry	Arkansas River (Offstream)	Private	6,300	9,916
Dye Lake	Arkansas River (Offstream)	Private	7,990	[c]
Holbrook No. 1	Arkansas River (Offstream)	Private	7,420	[c]
CF & I No. 3	Arkansas River (Offstream)	Private	8,530	[c]

[a] Reservoirs with storage capacity total in excess of 5,000 acre-feet.
[b] 20,000 acre-feet of storage will be transferred to conservation storage in the authorized Trinidad Reservoir.
[c] Information not available.

Source: Bureau of Reclamation [9], and Federal Power Commission [10]

Table V-4

Existing Transbasin Diversion Projects [a]

Project Name	Period of Diversion Record (years)	Average Annual Diversion (Ac.-Ft.)	Diversions Oct. 1962-Sept. 1963 (Ac.-Ft.)
Fremont Pass Ditch	35	527	None
Columbine Ditch	33	1,023	952 [b]
Ewing Ditch	56	1,211	393 [b]
Wurtz Ditch	32	2,096	1,569 [b]
Busk-Ivanhoe Diversion Tunnel	39	4,444	3,700
Twin Lakes (Independence Pass) Diversion Tunnel	29	35,831	31,940
Larkspur Ditch	29	134	12
Medrano Ditch [c]	[d]	[d]	[d]
Hoosier Pass Tunnel [e]	12	7,022	9,860

[a] All diversions from Colorado River basin except where noted.
[b] Previously unpublished figures obtained from city of Pueblo.
[c] Diversion from Rio Grande basin.
[d] Information not available.
[e] Diversion to South Platte basin then to Arkansas basin from watershed in Summit County - source of water supply for Colorado Springs.

Source: Bureau of Reclamation [9]

Table V-5

Authorized Water Supply Projects
in the Study Area

Feature Name	Location	Storage Capacity		Ownership	Principal User
		Conservation (ac.-ft.)	Total (ac.-ft.)		
Trinidad	Purgatoire River	20,000	114,500	Corps of Engineers [a]	Flood Control, Conservation
Sugar Loaf [b] (Enlargement)	Lake Fork	121,000	130,000	Bureau of Reclamation	Power, Conservation
Twin Lakes [b] (Enlargement)	Lake Creek	93,192	166,179	Bureau of Reclamation	Power, Conservation
Pueblo [b]	Arkansas River	233,985 [c]	356,821	Bureau of Reclamation	Flood Control, Power, Conservation

[a] The Trinidad project would be constructed, operated and maintained by the Corps of Engineers.
[b] Part of the proposed Fryingpan-Arkansas Project Development.
[c] There is 92,799 acre-feet in the joint use pool in addition to the 234,000 acre-feet in the conservation pool.

Source: Bureau of Reclamation [9]

Quality of Water Available

The water of the Arkansas River and its tributaries in the headwaters (above Canon City) is generally of excellent chemical quality. Some localized pollution from acid mine drainage occurs in the area of Leadville and is evident in California Gulch (tributary to the Arkansas River near Leadville), and in the Arkansas River for a few miles downstream from this point. Studies are being made by the Fish and Wildlife Service and the Geological Survey to determine the location and extent of pollution (heavy metals) from mine drainage in this area, and the effects of these substances on the stream environment. Upon completion of these studies, it is expected solutions to the control of pollution at or near the source will be developed.

As shown by table V-6, the mineral quality of the Arkansas River becomes progressively worse downstream from Canon City. This is attributed to accumulation of salts from return flows from irrigated lands and from solids picked up from soluble rock strata along the tributary streams.

High mineral concentrations are found in the Arkansas River below the Nepesta water quality gage and in all the major tributaries shown on the table. For all the points of water quality record shown, only those locations on the Arkansas River main stem at Pueblo and above and on the Purgatoire at Trinidad contain dissolved minerals within the upper limits recommended by the Public Health Service Drinking Water Standards-1962. 11/

However, low mineral concentrations are found near the headwaters of most of the tributaries throughout the study area. Fountain Creek above Monument Creek is now used as a source of water supply by the city of Colorado Springs (see table VII-1). Chemical quality data are not available for the stream at this location, however, dissolved solids concentrations in the city's water supply indicate good chemical quality, well within the upper limits of the above referenced drinking water standards. A summary of the chemical quality of study area municipal surface and ground water supplies is shown in table V-7.

The quality of the Arkansas River water for irrigation purposes ranges from excellent in the upper reaches to suitable at the Colorado - Kansas State line. 12/ Most of the areas now under irrigation in the study area have been irrigated for approximately 70 years with about the same quality of water. Some lands have gone out of production due to inadequate drainage and poor quality of water; however, most of the soil now being irrigated has adequate permeability and subsurface drainage to permit leaching when leaching water is available. All major crops grown in the Arkansas Valley are salt tolerant. 12/

Table V-6

Chemical Character of Surface Waters for Selected Points in the Study Area
(mg/l)

		Dissolved Solids	Chlorides	Sulfates (SO_4)
Arkansas River at Cannon City	Arith Mean 1/	177	9	34
Period of Record	Max.	226	15	43
Nov 1963 - Sep 1964	Min.	92	3	21
Arkansas River near Pueblo		466	11	206
Period of Record		740	16	369
Nov 1963 - Sep 1964		193	5	63
Fountain Creek at Pueblo		1945	62	1056
Period of Record		2550	78	1390
Nov 1963 - Sep 1964		1350	49	679
St. Charles at Mouth		1605	-	-
Period of Record		1687	-	-
Aug 1952 - Mar 1953		1468	-	-
Huerfano River at Undercliffe		1041	32	555
Period of Record		1558	46	872
Feb 1945 - Jan 1946		510	16	226
Arkansas River near Nepesta		700	21	337
Period of Record		957	31	490
Nov 1963 - Sep 1964		296	7	109
Apishapa River near Fowler		2051	36	1215
Period of Record		3190	53	1940
Nov 1963 - Sep 1964		426	9	185
Timpas Creek at Mouth		1575	-	-
Period of Record		1687	-	-
Aug 1952 - Mar 1953		1458	-	-

	Dissolved Solids	Chlorides	Sulfates (SO_4)
Arkansas River at La Junta	1213	30	650
Period of Record	2240	59	1250
Jan 1964 - Sep 1964	491	9	199
Adobe Creek at Mouth	2276	-	-
Period of Record	2535	-	-
Aug 1952 - Mar 1953	2090	-	-
Arkansas River at Las Animas	2347	81	1358
Period of Record	3320	118	1890
Nov 1963 - Sep 1964	974	18	496
Purgatoire River at Trinidad	279	7	63
Period of Record	392	14	114
Mar 1945 - Feb 1946	134	2	15
Purgatoire River - 14 miles N.E. of Trinidad	3251	47	1902
Period of Record	4654	85	2744
May 1945 - Jan 1946	834	14	348
Purgatoire River near Las Animas	3685	105	2422
Period of Record	5090	147	3070
Nov 1963 - Sep 1964	1040	12	547
Arkansas River Below John Martin Res.	3400	122	1940
Period of Record	4460	168	2590
Nov 1963 - Sep 1964	636	16	449
Arkansas River Below John Martin Res.			
Period of Record (Long Term)	2454	83	1437
Oct 1947 - Jul 1949	4510	180	2590
Jan 1951 - Sep 1964	470	11	219

Source: Geological Survey, 13/, and Bureau of Reclamation 14/

1/ Time Weighted Average

	Zinc	Copper	Iron	Manganese	Dissolved Solids	pH	Sulfates
Leadville Drain at Leadville							
Date of Analysis							
7- 7-65					641	7.3	372
9-21-65					526	7.1	291
3- 7-66	12.0	0.2	14.8	4.2	662	7.1	362
5-17-66	8.7	0.7	14.0	1.0	702	7.0	420
California Gulch at Malta							
Date of Analysis							
7- 8-65	230	7.0	34.0	340.0	868	3.3	565
9-21-65	40	1.45	1.67	8.5	870	4.5	559
3- 8-66	32.2	0.18	1.33	9.7	794	6.2	556
5-18-66	88	-	2.3	20.8	700	5.9	463

Source: Unpublished data - U. S. Geological Survey 15/

Table V-7

Chemical Quality Municipal Water Supplies in the Study Area

County	Municipality	Date	pH	Chloride (mg/l)	Sulfate (mg/l)	Total Hardness as $CaCO_3$ (mg/l)	Dissolved Solids (mg/l)
Lake	Leadville	6-28-60	7.0	0.0	18.0	88.0	99.0
Chaffee	* Buena Vista	6-29-60	6.9	0.0	4.5	40.0	57.0
	* Salida	6-30-60	7.5	2.6	16.0	153.0	215.0
Fremont	Canon City	9-21-60	7.5	3.9	28.0	95.0	138.0
	Florence	9-21-60	7.8	0.0	15.0	123.0	166.0
Pueblo	Pueblo	5-24-51	7.8	6.0	117.0	162.0	269.0
		9-19-60	7.5	6.4	113.0	186.0	298.0
El Paso	Colo. Springs	4-12-50	7.4	2.5	4.0	19.0	33.0
		5-25-51	8.1	15.0	20.0	154.0	244.0
		9-23-60	6.8	9.5	17.0	60.0	111.0
Huerfano	Walsenburg	5-26-60	7.6	0.0	13.0	97.0	115.0
Otero	* Fowler	7-28-60	7.7	180.0	432.0	304.0	1160.0
	Rocky Ford	9-27-60	7.0	38.0	768.0	808.0	1440.0
	* La Junta	7-28-60	7.4	44.0	875.0	848.0	1660.0
Crowley	* Sugar-City	7-27-60	7.7	46.0	476.0	197.0	1170.0
Bent	* Las Animas	10- 4-60	7.0	100.0	1520.0	1160.0	2850.0
Las Animas	Trinidad	6- 6-51	7.9	1.2	6.7	76.0	98.0
		5-10-60	7.2	0.1	9.8	117.0	140.0

*Entire supply from ground water.

Source: Geological Survey 16/

VI. THE ECONOMY

An economic evaluation was made of the 13-county upper Arkansas study area. The resulting projections of population and industrial growth serve as a basis for estimating future water use requirements and subsequent waste discharges.

Present

Economic Geography

The study area is located in southeastern Colorado and extends from the headqaters of the Arkansas River in the Rocky Mountains to John Martin Reservoir (see figure III-1). In the western portion of the study area mountains rise to elevations of more than 10,000 feet. In the foothills of the mountains are located the metropolitan areas of Pueblo and Colorado Springs. Between the Pueblo-Colorado Springs area dnd John Martin Reservoir is a rather flat river valley area oriented toward agriculture and irrigation. The different types of geography are the basis for the selection of subarea described in Chapter IV and shown in figure III-1. The study area had a 1960 population of 367,000. As shown in table VI-1 about three-fourths of the people in the study area resided in urban areas. Pueblo and Colorado Springs are the largest cities in the study area. El Paso and Pueblo Counties form the Pueblo-Colorado Springs Standard Metropolitan Statistical Areas and can be considered one large metropolitan area. In addition to Colorado Springs and Pueblo, other urban population centers include Security, Salida, Canon City, Florence, Leadville, Las Animas, Walsenburg, Trinidad, La Junta, and Rocky Ford. Security, Trinidad, Canon City, La Junta, and Walsenburg are the largest of these urban centers. As shown in table VI-1, total study area population increased from 248,000 in 1930 to 367,000 in 1960. Most of this increase occurred between 1950 and 1960. Total population in Area I was about stable and Area III experienced a 10,000 loss. These losses were more than accounted for by the increase of about 100,000 people in Area II which is the Pueblo-Colorado Springs metropolitan areas. In 1964, population of the study area was estimated at 416,000.[17] Again most of this increase occurred in Area II with small gains shown in Area I and very little change in Area III.

Table VI-1

Study Area Population

	1930		1940		1950		1960	
	Pop.	%	Pop.	%	Pop.	%	Pop.	%
Area I								
Urban	20,277	35.4	24,920	39.6	23,348	48.2	25,433	51.8
Rural	37,023	64.6	37,907	60.4	25,082	51.8	23,651	48.2
Total	57,300	100.0	62,827	100.0	48,430	100.0	49,084	100.0
Area II								
Urban	83,333	72.1	88,951	72.4	127,760	77.6	212,573	80.1
Rural	32,275	27.9	22,944	27.6	36,951	22.4	49,876	19.9
Total	115,608	100.0	122,895	100.0	164,711	100.0	262,449	100.0
Area III								
Urban	24,868	33.0	26,989	38.0	27,226	41.8	27,048	48.7
Rural	50,598	67.0	44,002	62.0	37,948	58.2	28,460	51.3
Total	75,466	100.0	70,991	100.0	65,174	100.0	55,508	100.0
Total Study Area								
Urban	128,478	51.7	140,860	54.9	178,334	64.1	265,054	72.2
Rural	119,896	48.3	115,853	45.1	99,981	35.9	101,987	27.8
Total	248,374	100.0	256,713	100.0	278,315	100.0	367,041	100.0

Source: Bureau of Census 18/

Resources Within the Area

The study area is served by four major airlines, six railroad lines, one interstate highway, four U. S. highways, as well as numerous state and local highways.

As shown in table VI-1 about 100,000 of the 367,000 people that live in the area in 1960 resided in rural areas. Much of the farm income was related to crop and livestock production in irrigated areas. In 1964, more than 75 percent of the total value of farm products sold was from the sale of livestock and livestock products. 19/ The most concentrated livestock producing area is in the La Junta - Rocky Ford area of Otero County where commercial cattle feeding is practiced on a fairly large scale. As shown in table VI-2, farm products sold in 1964 amounted to nearly $60 million. This was a

reduction in both livestock and crop sales from the 1959 value. Commercial vegetables, wheat, grain sorghums, and sugar beets account for most of the value of crops sold.

The number of acres irrigated in the Arkansas valley above John Martin has varied between 241,398 acres in 1954 up to nearly 397,000 in 1949. (See table VI-2.) The main crops irrigated included alfalfa hay, grain sorghums, corn, wheat, sugar beets, and vegetables. Most of the irrigation water is obtained either from the Arkansas River or from the alluvium of the Arkansas River, therefore, the number of acres irrigated is related to and varies with the quantity of water which flows down the Arkansas during irrigation season.

Table VI-2

Agricultural Statistics for the Study Area
1944 - 1964

	1944	1949	1954	1959	1964
Number of Farms	8,210	7,456	6,601	5,278	4,669
Acres of Cropland Harvested	656,036	692,948	441,738	487,786	345,957
Value of all Crops Sold*	13,257	15,780	8,637	15,102	12,638
Value of all Livestock and Livestock Products Sold*	25,861	35,600	30,442	52,588	49,203
Total Value of All Farm Products*	39,118	51,380	39,079	67,690	61,841
Acres Irrigated	374,790	396,970	241,398	356,654	290,942

*All values in 1,000's of 1960 dollars.

Source: Bureau of the Census [19/]

The Arkansas River basin has been famous for mining activities since the mid-1800's. Mining communities such as Cripple Creek, Fairplay and Leadville became famous for gold, lead, and silver mining before 1900. In recent years, the mining of gold, lead, and silver has practically ceased due to the high cost of extraction and processing of these metals. Molybdenum an important metal used in the manufacturing of steel is produced in the headwaters of the Arkansas River in Lake County. More than 75 percent of the Nation's molybdenum supply is produced in this area. [17/] Berllium, a glamour metal used in rocket construction, is found in Teller County, west of Lake George. Uranium, vanadium, and thorium are just a few of the other new names in Colorado mining today. About one-fourth of the State of Colorado is underlain by coal. In fact, the State ranks first in bituminous coal reserves. Much of this tremendous supply

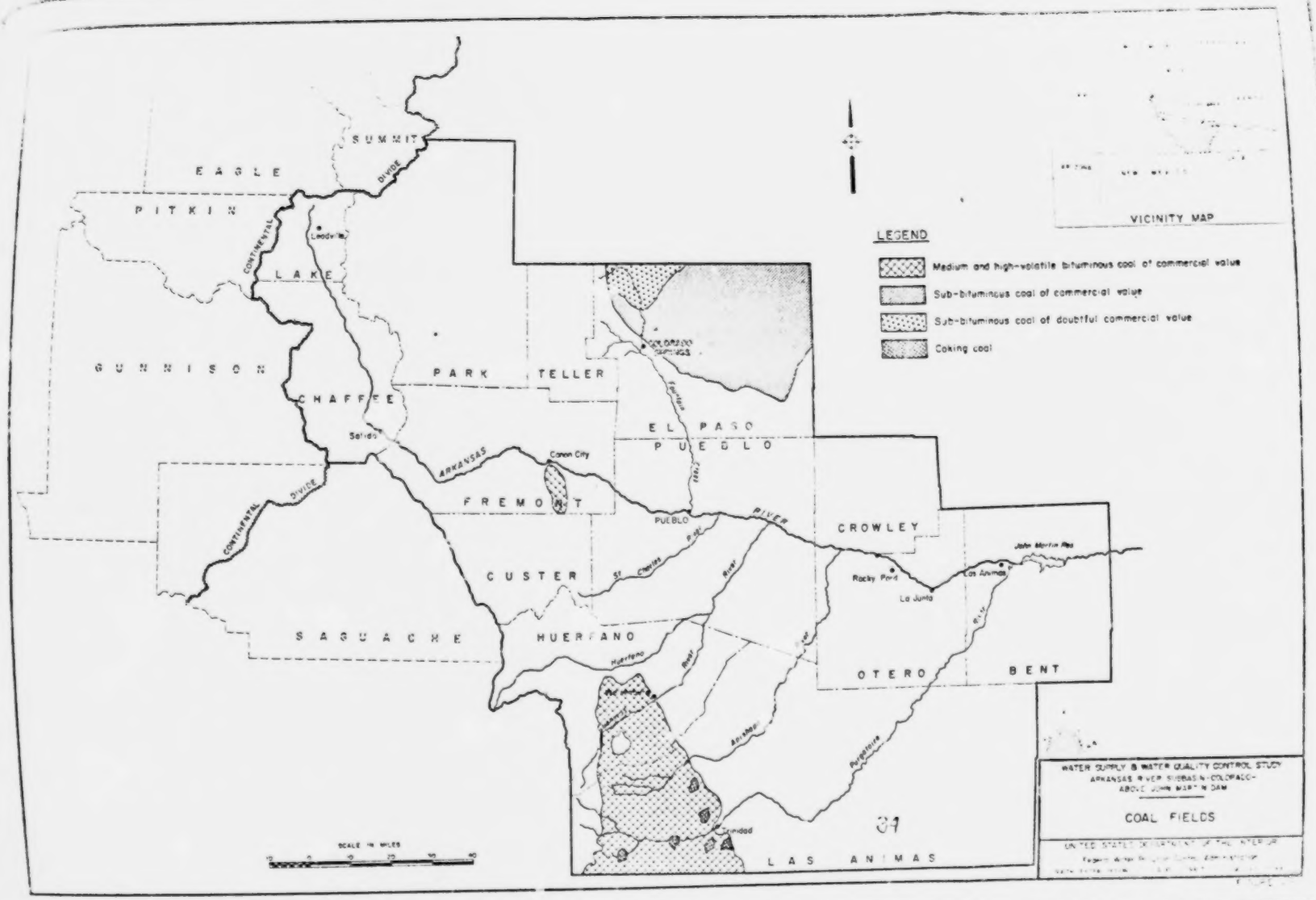
lies in the Arkansas valleys of Las Animas, Huerfano, Pueblo, and El Paso Counties. Although used mostly for industrial fuel, coke and electrical power generation, coal is showing new signs of activity. Research by various mining universities, laboratories, and government agencies has developed new uses for coal and such important by-products as chemical tars, napthaline, benzoil, and sulfates. The location of coal fields is shown in figure VI-1.

Manufacturing

More than 20,000 people or about 17 percent of the total labor force in 1960 were employed in manufacturing, as shown in table VI-3. The most significant employers are primary metals, fabricated metals, and food and kindred products. These three industries account for more than 75 percent of the total manufacturing employment. Most of the employment in the primary and fabricated metals industry is by the Colorado Fuel and Iron Corporation in Pueblo. Colorado Fuel and Iron obtains its coking coal from its own mines within the Arkansas valley, (see figure VI-1). It also obtains all of its limestone in the same area. Iron ore is brought in from outside the Arkansas valley, largely from Wyoming and southwestern Utah.

The main products produced by Colorado Fuel and Iron include wire and wire products, structural and rolled products, tubular goods and pipe, rails and accessories, and chemical products. 20/ The markets for these products are generally regional, however, some products find national distribution.

Food and kindred products processing is one of the leading industries in the Arkansas valley, employing more than 2,500 people in 1960. 21/ The main food processing which occurs includes meatpacking canning, sugar beet processing, and the processing of dairy products. Much of the meat processing is a result of decentralization of market facilities to areas where fed cattle are raised. This has been caused by increased cattle feeding, improved refrigeration, faster transportation, and the fact that it is more economical to transport live cattle once to a feedlot than to continually haul feed to cattle in some feeding area. The main cattle feeds used in this area are alfalfa, corn grain sorghums and sugar beet pulp; all of which are very plentiful. The Arkansas valley is very well adapted to the growing of commercial vegetables. This ready source of supply is the reason for the location of five major canning plants in the area. In the last 12 years, the number of canning plants has decreased from five to two, however, the output of the two canneries located in the Arkansas valley today is greater than that of all five previously. The main crops canned include tomatoes, pickles, peas, and snap beans.


SUMMIT
EAGLE
PITKIN
LAKE
GUNNISON
CHAFFEE
PARK
TELLER
EL PASO
PUEBLO
FREMONT
CUSTER
SAGUACHE
HUERFANO
CROWLEY
OTERO
BENT
LAS ANIMAS
CONTINENTAL DIVIDE
ARKANSAS RIVER
PUEBLO
Leadville
Salida
Canon City
Colorado Springs
Rocky Ford
La Junta
Las Animas
John Martin Res
Trinidad
LEGEND
Medium and high-volatile bituminous coal of commercial value
Sub-bituminous coal of commercial value
Sub-bituminous coal of doubtful commercial value
Coking coal
VICINITY MAP
SCALE IN MILES
WATER SUPPLY & WATER QUALITY CONTROL STUDY
ARKANSAS RIVER BASIN-COLORADO-
ABOVE JOHN MARTIN DAM
COAL FIELDS
37

Most of the input for this industry comes from the immediate areas surrounding the canning factories. However, northern Colorado and Texas are also major sources of input.

In 1959, over 15,000 acres of sugar beets were irrigated in the study area. These sugar beets plus some beets brought in from surrounding areas are processed at the Rocky Food Sugar plant.

Most of the dairy manufacturing is centered around the urban areas and is processing of milk and milk products for the large urban populations.

Table VI-3

Study Area Labor Force and Population
1950 and 1960

	1950		1960	
	Number	Percent	Number	Percent
Agriculture, Forestry and Fisheries	10,914	11.3	6,753	5.6
Mining	3,576	3.7	3,243	2.7
Manufacturing	13,466	14.0	20,262	16.8
Primary Metals	7,337	7.6	8,116	6.8
Fabricated Metals	1,041	1.1	5,859	4.9
Food & Kindred Products	1,772	1.8	2,554	2.1
Other Manufacturing	3,266	3.5	3,733	3.0
All Other Employment	63,481	65.9	83,586	69.5
Unemployed	4,893	5.1	6,444	5.4
Total Labor Force	96,330	100.0	120,288	100.0
Total Population	278,315		367,019	
Labor Force % of Population		34.6		32.8

Source: Bureau of Census 21/

The largest single source of employment in the Arkansas valley is military activities. In 1964, there were an estimated 26,500 military personnel in the area.[22] Civilian employment in 1964 was estimated at 9,000. Most of these government employees are located at four major military facilities in El Paso and Pueblo Counties. They include Fort Garson, south of Colorado Springs, North American Air Defense Command (NORAD) headquarters at Ent Air Force Base in Colorado Springs, the Air Force Academy, north of Colorado Springs, and the Pueblo Army Depot, east of Pueblo. An estimated $50 million annually is added to the economy of the Colorado Springs area by the three military establishments in the Colorado Springs area. In addition to the military, there are five State and Federal institutions located in the area which affect the economy considerably. These institutions are the Colorado State Reformatory, the Colorado State Penitentiary, the Veterans Administration Hospital, the Colorado State Hospital, and Southern Colorado State College. These five institutions employed about 4,000 people in 1965.

The Colorado Springs area is generally oriented to tourism and has been for 75 years. Some of the attractions for tourist include the Royal Gorge at Canon City, Pikes Peak near Colorado Springs, Cheyenne Mountain Zoo in Colorado Springs, Seven Falls near Colorado Springs, Cave of the Wind at Manitou Springs, Santa's workshop at Cascade, the Rocky Mountain Kennel Club at Colorado Springs, the Air Force Academy north of Colorado Springs, and the Colorado Springs Fine Arts Center. These tourist attractions average about 4 million visitor days per year. [23]

The Arkansas River valley has long been known as one of the best hunting and fishing areas of the United States. The Arkansas River is known for its productivity of large brown trout and easy accessibility to the public. Big game hunting is also important in the Arkansas valley. In 1964 there were 360 elk, 7,151 deer, 765 antelope, 85 bear, 192 turkeys, and 22 bighorn sheep killed. [23]

The Future

Economic projections are necessary as a basis for estimating future municipal, industrial, and water quality control needs of the area. The recently completed regional study of the Arkansas-Red River systems was relied on as a major source of information for this study. [24] The projections presented reflect an updating of the Ark-Red study as well as information contained in studies made by the

State of Colorado and the Corps of Engineers. One of the most significant factors in the growth of the upper Arkansas area is the increased recreation and tourism anticipated in an economy which has more spare time. Also anticipated to have a marked effect on the growth of the Arkansas valley is the increased food processing necessary to feed an ever expanding population and increased extraction of the glamour metals mined in the area.

Based on part historic growth and an analysis of resources in each of the these subareas, population projections were made to assist in determining the needs for water supply and pollution control. Population projections for these subareas for the years 1980, 2000, 2020 and 2070 are shown in table VI-4.

Heavy industrial water users are expected to be the same industries which are presently located in the area. These include iron and steel production, and food and kindred products processing. Increases in food and kindred product output are anticipated to be mainly in the processing of sugar beets and meat. Iron and steel production is anticipated to be in the order of 2.5 million tons annually by the year 2020. This value was developed in the 1964 Public Health Service study. Food and kindred product processing is expected to triple by the year 2020.

Table VI-4

Population Projections for the Study Area
1960, 1980, 2000, 2020, and 2070
(1,000's)

	1960	1980	2000	2020	2070
Area I					
Urban	25	40	56	73	123
Rural	24	20	18	17	17
Total	49	60	74	90	140
Area II					
Urban	212	404	678	1,061	2,367
Rural	50	35	25	20	15
Total	262	439	703	1,081	2,382
Area III					
Urban	27	35	42	49	63
Rural	28	19	18	17	15
Total	55	54	60	66	78
Total Study Area					
Urban	264	479	776	1,183	2,553
Rural	102	74	61	54	47
Total	366	553	837	1,237	2,600

VII. WATER SUPPLY

Municipal Water Use

Municipal water uses include residential, public, commercial, and those industrial uses which are served by organized public water supply systems and are reflected in per capita water use.

Included in per capita quantities are losses in the distribution systems and treatment plants. Present per capita water use for major cities in the study area is about 260 gallons per capita per day (gpcd) with municipal water use averaging about 74 mgd. (See table VII-1.)

Future municipal water requirements are calculated by multiplying projected per capita water use by the projected study area population served by public water supply systems.

Projected per capita water requirements for the study area are based on a study of water use trends throughout the Arkansas and Red River basins. 24/

As part of the study, investigations were made to learn if variations noted in per capita water use are associated with any of the usually investigated criteria.

Comparisons were attempted with municipal populations - size group, population density, personal income, price of water, rainfall, climate factor, aridity factor, distance from a single isohyetal line and combination of these variables. The effects of metering were also observed.

From the study, it was concluded that future per capita water requirements of the Arkansas River basin in Colorado will eventually become stabilized at around 200 gpcd and reflect a more conservative use of water. This is particularly indicated since much of the population now served by municipal water supply systems in the study area is unmetered.

Industrial Water Use

Industrial water requirements are those significant quantities of water required in the manufacture of goods and the processing of materials more appropriately measured in water use per employee or unit(s) of production. These demands for water supply are exerted by heavy water-using industries such as those described in Senate Select Committee Print No. 8. 25/ Within the study area such industries include thermal power generation, iron, and steel production, and food and kindred products production. Water needs of these industries may be supplied by public water supply systems, private supplies or a combination of both.

Table VII-1

Principal Study Area Municipal and Industrial Water Supplies

County Area	Designation	Est. Population Served	Present Average Demand (mgd)	Surface Water Source	Surface Water Yield (mgd)	Ground Water Source	Ground Water Yield (mgd)
Lake	Climax	1,610	0.34	Buhers Lake, Chalk Mountain Res.	1.0 a/ b/		
	Leadville	6,000	1.50	Evans & Iowa Creeks and Elkhorn Mine	4.0 a/ c/		
Chaffee	Buena Vista	1,810	.50	Cottonwood Creek	1.3	2 wells & infiltration gallery	1.3
	Salida	5,000	1.50	South Arkansas River	4.5	4 wells & 2 infiltration gallerys	3.0
Fremont	Canon City	13,000	2.50	Arkansas River	10.0		
	Florence	3,200	0.60 a/	Newlin, Mineral and Adobe Creeks	1.2	2 wells	1.0 a/
Huerfano	Walsenburg	6,500	2.00	Cucharas River	3.5		
Pueblo	Pueblo	115,000	34.00	Arkansas River	126.0 d/ e/	6 wells	6.0 a/
El Paso	Colo. Spgs.	85,000	19.20	Blue & S. Platte River) Fountain Creek & several tributaries) in the Pikes Peak Watershed	33.0		
				Homestake Reservoir	33.0 f/		
	Security	12,000	2.50			14 wells	7.2
Otero	Fowler	1,300	0.10 a/			5 wells & 9 springs g/	4.0 a/
	Rocky Ford	5,000	1.35	Arkansas River	h/	2 wells	2.3
	La Junta	9,000	2.70			8 wells	10.0
Crowley	Ordway	1,200	0.20			3 wells	1.2 a/
	Sugar-City	550	0.10			4 wells	1.6 a/
Bent	Las Animas	3,400	1.50			4 wells	3.4
Las Animas	Trinidad	13,200	3.25	Monument Lake	8.0		
	TOTAL	282,770	73.84		225.5		41.0
	Average gpcd = 261						

a/ Estimate.
b/ Mining Town. Water supply owned by local Molybdenum Company.
c/ Leadville also has decreed water rights in the Arkansas River which could be used to meet any additional long-range water needs.
d/ Present streamflow water rights of the City of Pueblo including direct river flow rights, transmountain diversions and storage in Clear Creek Reservoir total about 50 mgd.
e/ Includes approximately 76 mgd of industrial water supply from storage owned by the Colorado Fuel and Iron Corp. in the headwaters of the basin.
f/ The Homestake Res., a private development, now under construction will provide 37,000 acre-feet/year for the Colorado Springs area by way of transmountain diversion.
g/ Municipally owned wells supply a local irrigation system.
h/ No estimate available.

NOTE: A portion of the information used in this table was received from Geological Survey, local water officials, and Regional Planning Commissions in telephone conversations.

Source: Public Health Service 26/ and Geological Survey 16/

Study area projections of thermal power water needs in a 1964 Public Health Service report [24] are based on investigations made in the aforementioned study. As indicated by this report, thermal power generation in the study area will reach a level of about 63 kilowatt-hours per capita per day by the year 2020. This power requirement is anticipated in addition to that supplied by hydroelectric development. The estimated consumptive unit cooling water use by thermal power installations in the study area by the year 2020 is 0.7 gallons per kilowatt-hour.

In the 1964 Public Health Service report [24] referenced above, iron and steel production for the study area was projected to increase to 2.5 to 3 million tons yearly by the year 2020. Once-through water requirements for this amount of production (based on current practices in the study area) would be on the order of 250 mgd. However, representatives of the iron and steel industry in the study area indicate that by recirculating cooling waters and making use of ammonia liquors for quenching, present iron and steel production capacity (1.3 million tons yearly) could be tripled without increasing their water supplies. Projected water requirements of the study area, therefore, reflect a more conservative water use by the iron and steel industry in future years.

Water needs of the food processing industry in the study area as in the case of the other industries discussed are based largely on the previous study [24] of this area.

Though mining operations are widespread in the study area, water used by this industry is not considered here. Water is often encountered as a by-product of the mining operation and such water is generally adequate to meet the industry's water needs. Also, water is often reused extensively as in the case of the molybdenum operation at Climax. Here water used to carry waste material from the mills and by-products plant is distributed in a tailing pond along the crest of the tailing dam. There the water runs off and permits small particles of waste material to settle out. This water is then reclaimed and pumped back to a small company owned water supply reservoir which receives some flow from spring and summer runoff in Ten Mile Creek. The supply serves the company's industrial water needs.

Rural Water Use

A small portion of the total water needed in the study area is that of rural water supplies for purposes other than irrigation. Generally, this includes domestic water for that portion of the population not served by municipal water systems, water for the maintenance of livestock and supplies for small rural communities with less than 2,500 population. Projected requirements for rural water use are based on a per capita water use of 136 gallons per day (gpd).

2070 Water Requirements

Municipal, industrial, and rural water needs of the study area beyond the year 2020 are based on seasoned extrapolation of projections developed through the year 2020. As shown by table VII-2, the total average daily water requirement for municipal, industrial, and rural purposes is expected to reach about 730 mgd in the study area by the year 2070.

Per capita municipal and rural water requirements through the year 2070 are based on a continuation of water use rates established for the first 50-year projection. An increasing tendency toward conservative industrial water use is reflected in a study of industrial water requirement projections.

Total per capita water use for the three water-using segments discussed is therefore projected to be about 280 gpcd by the year 2070 as compared to about 320 gpcd in the year 2020.

Authorized and presently developed municipal, industrial, and rural water supplies will be adequate through the year 1990. Further development will require additional importation of water from other basins, a reapportionment of water resources within the basin, or an intensive program for renovation and reuse of waste water. At the present time, adjudicated water rights for study area resources far exceed the quantity of water normally available.

A large portion of the water resources of the basin are now appropriated for irrigation. However, it is expected that much of the good quality water available or planned for development in the basin will eventually be directed towards satisfying municipal and industrial water needs and that treated municipal and industrial waste discharges will be used to make up deficiencies in irrigation water needs.

Water from the Arkansas River and tributaries above Pueblo could satisfy anticipated municipal and industrial needs through the year 2040; thereafter, demands will have to be satisfied by water imports or reuse of waste water. A planning report [27] prepared for the Colorado Division of Commerce and Development indicates that approximately 200,000 acre-feet of water in the Colorado River basin is available for development. Water resources in the Arkansas River basin below Pueblo are generally poor in mineral quality and are not desirable for municipal and industrial supplies but can be used for limited industrial applications, irrigation, and for dilution of wastes.

Table VII-2

Projected Study Area Water Requirements - 1980, 2000, 2020 & 2070

SUB-AREA Counties	Population Served (1,000) Municipal Water Supply Systems	Population Served (1,000) Rural Water Supplies 1/	Water Requirement (mgd) Municipal	Rural	Industrial	Total
AREA I - Chaffee, Custer, Fremont, Lake, Park, Teller, Huerfano						
Year						
1980	40	20	8.0	2.7	2.6	13.3
2000	56	18	11.2	2.5	3.3	17.0
2020	73	17	14.6	2.4	4.0	21.0
2070	123	17	24.6	2.4	6.2	33.2
AREA II - Pueblo, El Paso						
Year						
1980	404	35	80.8	4.7	97.4	182.9
2000	678	25	135.6	3.4	108.7	247.7
2020	1061	20	212.2	2.7	127.0	341.9
2070	2367	15	473.4	2.0	183.0	658.4
AREA III - Bent, Cowley, Las Animas, Otero						
Year						
1980	35	19	7.0	2.6	11.4	21.0
2000	42	18	8.4	2.4	14.6	25.4
2020	49	17	9.8	2.3	18.0	30.1
2070	63	15	12.6	2.0	22.4	37.0
STUDY AREA						
Year						
1980	479	74	95.8	10.0	111.4	217.2
2000	776	61	155.2	8.3	126.6	290.1
2020	1183	54	236.6	7.4	149.0	393.0
2070	2553	47	510.6	6.4	211.6	728.6

VIII. WATER QUALITY CONTROL REQUIREMENTS

General

Water quality studies are essential to effective management of water resources. Frequently it is found that streamflow must be regulated to protect, preserve or enhance the quality of water for established or potential beneficial uses.

Congress emphasized the importance of water quality control as it applies to our Nation's water resources by the enactment of the Federal Water Pollution Control Act, Public Law 84-660, as amended by Public Law 87-88. Under the provisions of this Act, consideration must be given to the inclusion of storage for regulation of streamflow to control water quality in any reservoir being planned by a Federal agency. However, it was also emphasized that storage for use in regulation of water quality is not to be provided as a substitute for adequate treatment of wastes.

In determining the amount of water from storage required to preserve the quality of a stream, it is necessary to make allowances for natural flows that could be expected to occur in the stream in the absence of the proposed project. Estimated natural streamflows are shown in Appendix A, figures A-1 and A-2. Figure A-3 shows flows expected in the main stem of the river after completion of the proposed Bureau of Reclamation Fryingpan-Arkansas project.

Quality Criteria

After consideration of the present and potential pollutants in the area and possible measures for control, it was concluded that dissolved oxygen and dissolved solids were most appropriate to use as a basis for evaluation of the possible use of flow regulation for control of the quality of surface waters in the study area.

Dissolved Oxygen.- Small dissolved oxygen concentrations are necessary in streams to prevent nuisance conditions and degradation of aesthetics of the streams and contiguous land area. It sometimes is necessary to maintain higher concentrations when the stream is to be used for propagation of fish and other aquatic life, recreation, and water supplies. Following are minimum desirable dissolved oxygen concentrations adopted for this study:

Main Stem of Arkansas River	
From: Source above Leadville	
To: Canon City	6.0 mg/l
From: Canon City	
To: Pueblo	5.0 mg/l
From: Pueblo	
To: John Martin Reservoir	4.0 mg/l
Tributaries above Fountain Creek	6.0 mg/l
Tributaries below Fountain Creek (minimum concentration in headwater areas is 6.0 mg/l)	3.0 mg/l
Fountain Creek	
From: Source	
To: Confluence with Monument Creek	6.0 mg/l
From: Confluence with Monument Creek	
To: Confluence with Arkansas River	4.0 mg/l

Dissolved Oxygen (D.O.) concentrations listed above are consistent with state stream standards with two exceptions; state standards do not include a minimum concentration for Fountain Creek below its confluence with Monument Creek and the minimum concentration in the Arkansas River below Pueblo is set at 3.0 mg/l except for a small reach near Rocky Ford that is set at 4.0 mg/l. Expected changes in stream use will make increased D.O. concentrations desirable. Study area growth projected to the year 2070 will most likely involve urbanization of much of the area surrounding Fountain Creek. Also increasing waste discharges and reduction of irrigation due to urbanization of farm lands will produce perennal streamflow. These factors probably will result in the development of recreational areas along the creek making aesthetics the primary benefical use of the stream. Use of the Arkansas River below Pueblo is expected to be limited primarily to irrigation with minor industrial use throughout the study period. However, plans for channel improvement include development of eighteen river bed areas, that would be cut off by channel straightening, for recreation and fish and wildlife enhancement. Prevention of nuisance conditions and preservation of the aesthetics of the river will become more important when the recreational areas are established.

It was felt that minimum D.O. concentrations of 4.0 mg/l should be used in our analysis of the D.O. profile of both Fountain Creek and the Arkansas river below Pueblo. It was recognized that lower minimum D.O. concentrations could possibly prevent undesirable

nuisance and aesthetic conditions. However, a high percentage of the flow in both streams will be waste water and high biochemical oxygen demand concentrations will exist simultaneously with minimum D.O. concentrations in the flowing stream. If a substantial oxygen reserve is not maintained in the stream, anaerobic conditions could develop very rapidly in pools and diversion ditches or in any stream reach where the velocity of flow is reduced. Therefore, it was assumed that the oxygen profile developed in our computations should not fall below 4.0 mg/l.

Total Dissolved Solids.- Restrictions on dissolved solids concentrations in drinking water are generally based on palatability requirements. In the Public Health Service Drinking Water Standards-1962 11/ the recommended upper limit for the total dissolved solids concentration in a water supply is 500 mg/l, where, in the judgment of the reporting agency and the certifying authority, other more suitable supplies are or can be made available. No limitations have yet been established on the quantity of dissolved solids an individual can safely consume. Many communities in the United States and in foreign countries use water having a concentration of dissolved solids in excess of 500 mg/l.

Restrictions on dissolved solids for uses other than drinking water are highly variable. Generally, however, supplies with concentrations above 1,000 mg/l are undesirable for most uses.

Inorganic Pollutants

Surface water quality in the study area is degraded by heavy metals and acids emanating from abandoned mining operations in the vicinity of Leadville, Colorado; acids released from exposed mineral deposits at the head of the South Fork of Lake Creek; and irrigation return flows. However, improving stream quality by providing supplemental flows for dilution of the inorganic pollutants is not recommended.

Efforts have been made to determine the extent of pollution from heavy metals and acid emissions in the areas mentioned above. More detailed studies will be necessary before control methods are developed. However, reduction of the pollution load near the source will probably be required.

Above Pueblo, all surface waters, with the exception of the stream reaches affected by heavy metals and acid pollutants, are presently usable for municipal and most industrial purposes. However, below Pueblo irrigation return flows frequently raise dissolved solids concentrations above 2,000 mg/l. This pollution is so severe that it is not feasible to attempt to improve the mineral quality of

the waters by providing supplemental flows. This pollution has persisted for many years such that now surface waters below Pueblo are used principally for irrigation of salt tolerant crops, other uses are very limited. It does not appear that a reduction of mineral levels is necessary to maintain the present water use. To develop other uses, such as municipal and industrial process supplies,would require major reductions in the concentration of mineral pollutants. Present and anticipated water resources in the basin could not provide adequate supplemental flows for affecting this reduction. Industrial use for cooling could be further developed with present mineral levels.

Organic Pollutants

Organic pollutants are discharged to surface water courses by municipalities and industries throughout the river basin. However, municipal and industrial water use and waste production is largely centered in the areas of Pueblo, Colorado Springs, Canon City, La Junta, and Trinidad. Smaller but substantial quantities of water use and waste production occur in the vicinities of Leadville, Salida, Walsenburg, Rocky Ford, and Las Animas. At the present time, municipal waste discharges to study area streams are estimated to be between 40 and 50 mgd with a population equivalent (PE) of about 60,000. Biochemical oxygen demand (BOD) removal from wastes varies from 60 to 90 percent. However, the majority of the waste treatment plants provide secondary treatment with BOD removal approaching 90 percent. Principal sources of industrial water use and waste discharges are the iron and steel, food and kindred, and mining industries. In certain areas, the natural unregulated streamflow can not assimilate organic pollutants discharged to the streams without reducing the dissolved oxygen content below minimum desirable levels. Storage will be required to provide water for supplementing streamflow.

Table VIII-1 is a summary of the gross streamflow required to assimilate wastes discharged to study area streams. Table VIII-2 is a summary of supplemental streamflow requirements. Adequacy of flow determinations are based on a drought recurrence interval of once in 20 years.

Table VIII-1

Streamflow Required for Quality Control [1-4]

Point of Control	Year	Estimated Minimum Streamflow in cfs Needed to Assimilate Projected Future Waste Discharges						
		April	May	June	July	August	September	October
Leadville	2070	-	0.4	1.6	2.8	2.8	1.6	0.4
Buena Vista	2070	-	0.1	0.6	1.0	1.0	0.6	0.1
Salida	2070	-	0.5	1.9	3.4	3.4	1.9	0.5
Canon City	2070	-	0.9	3.7	6.5	6.5	3.7	0.9
Pueblo	2020	-	18.6	100.4	186.1	186.1	100.4	18.1
	2070	-	38.7	208.9	386.8	386.8	208.9	38.7
Colorado Springs	2020	26.9	50.4	140.9	251.9	251.9	140.9	50.4
	2070	61.9	116.0	324.9	580.2	580.2	324.9	116.0
Walsenburg	2070	0	0.4	2.5	3.6	3.6	2.5	0.4
Fowler	2070	0.1	0.2	0.4	0.6	0.6	0.4	0.2
Rocky Ford	2070	4.5	6.0	13.5	19.5	19.5	13.5	6.0
La Junta	2070	1.0	1.3	2.9	4.2	4.2	2.9	1.3
Las Animas	2070	0.7	0.9	2.0	2.8	2.8	2.0	0.9
Trinidad	2070	0.8	1.1	2.4	3.4	3.4	2.4	1.1

1/ Streamflow required to prevent depression of dissolved oxygen levels below desirable minimums.
2/ Waste treatment to provide 90 percent BOD removal was assumed in computations.
3/ Because of the prevailing low stream temperatures during the winter and early spring months and high reoxygenation rates, streamflow needs are expected to be negligible during some months. Needs are negligible during months omitted from the table.
4/ Supplemental streamflow requirements are presented in table VIII-2

Table VIII-2

Projected Supplemental Streamflow
Required for Water Quality Control

% BOD Removed from Wastes		Supplemental Flow Needed (1,000 ac.-ft. per year) Year 2020 90	93	99	Year 2070 90	93	99
Point of Control	Stream						
Colorado Springs[1]	Fountain Creek	55.1	21.9	0	126.9	50.4	0
Pueblo[2]	Arkansas River	0	-	-	85.2	20.8	0
Rocky Ford	Arkansas River	0	-	-	0.6	-	-
La Junta	Arkansas River	0	-	-	0.2	-	-
Las Animas	Arkansas River	0	-	-	0.1	-	-

1/ Dry stream conditions were assumed.
2/ Computation based on the assumption that Pueblo Reservoir was completed.

IX. WATER QUALITY CONTROL METHODS

General

From data presented in table VIII-2, it can be seen that control of surface water quality (dissolved oxygen content) will be required in only two study area streams, Fountain Creek below Colorado Springs, and the Arkansas River below Pueblo (see figure IX-1). In all other streams, natural flow will be adequate to assimilate properly treated (90 percent BOD removal) organic wastes. Several methods were considered for controlling the quality in the two streams. Simplified cost analyses (see Appendix B) were made to compare the cost of providing storage for supplementing streamflow with the cost of other control methods. In addition to the methods analyzed in Appendix B, systems for stream aeration were examined. However, stream aeration was found to be impractical where dissolved oxygen levels above about 2.0 mg/l are to be maintained.

In the cost analyses, it was assumed that storage to be used for supplementing streamflows could be provided at seven potential damsites listed in table IX-1 (see figure IX-1). It was recognized that it most likely would be necessary to purchase water rights from irrigators if storage is provided. However, water released for quality control could be sold to downstream irrigators after it is mixed with flow in the stream where quality control is required. It was assumed that water sales would pay for the purchase of water rights, therefore, only the cost of structural facilities were included in cost comparisons.

The cost analyses are interesting in that they indicate that maximum use of flow regulation by construction of reservoirs, and release of stored waters would possibly provide the most economical method for water quality control in both Fountain Creek and the Arkansas River below Pueblo.

Water Quality Control in the Arkansas River below Pueblo

Planned releases from the Pueblo Reservoir to be constructed by the Bureau of Reclamation would provide adequate quality control streamflow in the Arkansas River below Pueblo through the terminal year (2070) of the study. However, it is expected that direct released to the river below the reservoir will gradually be reduced from the year 1990 to the year 2040 due to increases in appropriations in and above the reservoir for water supplies.

Quality control computations in this study are based on the assumption that by the year 2040 development will progress to the point that the entire flow of the Arkansas River above Pueblo, Colorado, will be first used for municipal and industrial supplies prior to discharge as waste water to the stream system below Pueblo for subsequent

use for irrigation. By the year 2030, streamflow below Pueblo Reservoir will not be adequate for quality control. Storage below Pueblo will then be needed.

Table IX-1

Potential Damsites - Locations and Estimated Reservoir Yields [1/]

Site	Location	Average Annual Yield (ac.-ft.)	Average Annual Yield (mgd)
Ute Pass Damsite	Fountain River above Manitou Springs, Colorado	30,000	26.9
Fountain Creek Damsite	Fountain Creek near Pinon, Colorado	15,800	14.1
Pleasant View Damsite	St. Charles River near Pueblo, Colorado	14,100	12.6
Welton Damsite	Huerfano River about 5 miles above mouth	14,000	12.5
Apishapa Damsite	Apishapa River about 6 miles above mouth	24,000	21.5
Timpas Damsite	Timpas Creek about 10 miles above mouth	20,000	17.9
Adobe Damsite	Adobe Creek about 5 miles above mouth with diversion from Horse Creek into Adobe Creek	20,000	17.9
Purgatoire Damsite	Purgatoire River about 18 miles above mouth	20,100	18.0
	Total	158,000	141.4

[1/] Estimated yields are a function of the recorded flows and do not take water rights into consideration.

Source: Corps of Engineers

The following method was found to be the least costly of all those considered to preserve the quality of water in the Arkansas River below Pueblo:

Date	Action
1975	Complete Pueblo Reservoir for streamflow regulation.
2030-2055	Complete the following reservoirs to provide water for supplementing Arkansas River flows.

Year	Reservoir	Quantity Water Provided (acre-feet/year)
2030	Pleasant View	14,100
2032	Welton	14,000
2034	Apishapa	24,000
2038	Timpas	20,000
2055	Adobe	12,900

Water Quality Control in Fountain Creek

With treatment facilities that remove only 90 percent of the BOD of wastes discharged to the stream, utilization of all water resources potentially available within the Fountain Creek basin for supplementing flows still would not preserve the stream's quality. Advanced waste treatment facilities (facilities that will remove more than 90 percent of the BOD of the wastes) will be needed.. However, cost analyses presented in Appendix B (see table B-1 and B-3) indicate that it would be economically advantageous to provide as much storage as possible for quality control in lieu of additional treatment. The following method was found to be the least costly of all those studied for controlling the quality of water in Fountain Creek:

Date	Action
1970	Complete Ute Pass Reservoir to provide 30,000 acre-feet of water per year for supplementing streamflow. Provide waste treatment facilities capable of 90 percent BOD removal.
1990	Complete Fountain Creek Reservoir to provide 15,800 acre-feet of water per year for supplementing streamflow. Provide waste treatment facilities capable of 90 percent BOD removal.
2010	Start modifying waste treatment facilities to provide 93 percent BOD removal. All facilities (228 mgd capacity) must be modified by 2060.
2060	Construct waste treatment facilities to provide 99 percent BOD removal from all wastes produced in excess of 228 mgd.

Fortunately, approximately 94 percent of the demand for supplemental flows would occur during the irrigation season. The combined waste and dilution flow could subsequently be diverted for irrigation above John Martin Reservoir. Releases during non-irrigation season, if not used for land conditioning, could be allowed to flow into the John Martin Reservoir and be stored for use below the reservoir during the following year.

Although not an alternative to storage, it should also be noted that it would be possible to route water from the Arkansas River through Fountain Creek by pumping to provide supplemental flows for a limited period of time possibly until the year 2010. At the same time, streamflow in the Arkansas River below Fountain Creek would not be materially altered. After 2010, it would be necessary to provide storage on Fountain Creek or its tributaries for supplementing streamflow or construct advanced waste treatment facilities for 99 percent BOD removal. Pipeline facilities could then be utilized for a municipal water supply.

Discussion

Although it appears desirable and economically advantageous to provide storage for streamflow regulation to preserve water quality, changes in the water law of Colorado would possibly be required to obtain water rights for implementing a project for this purpose. Adjudicated water rights, primarily for agricultural use, already exceed water resources normally available. While water rights for domestic use can be aquired from irrigators by purchase through condemnation procedures, this method of aquisition is not now possible for purchasing water to be used for streamflow regulation. Under present law, water rights for this purpose would have to be purchased in the same manner as any other property right.

Some measure of flow regulation could possibly be implemented by agreements to allow storage of water appropriated for irrigation at strategic locations in the basin where releases for irrigation would provide a dual benefit. Since supplemental flows for quality control are needed during the irrigation season, releases from storage primarily for irrigation could increase streamflow where it is needed for quality control. As an example, it might be possible to transfer some storage from John Martin Reservoir to Ute Pass, Pleasant View, or Welton sites.

While appropriation of water for storage to be used exclusively for quality control in study area streams is not considered possible due to the scarcity of water resources, it does not appear impossible to develop flow regulating facilities that would provide supplemental flows where required for quality control through dual use of the available resources. Studies should be initiated in cooperation with State agencies to develop a comprehensive plan for regulation of flow

throughout the basin to gain optimum use of the limited resources available and to develop the legal base necessary for implementation of the plan.

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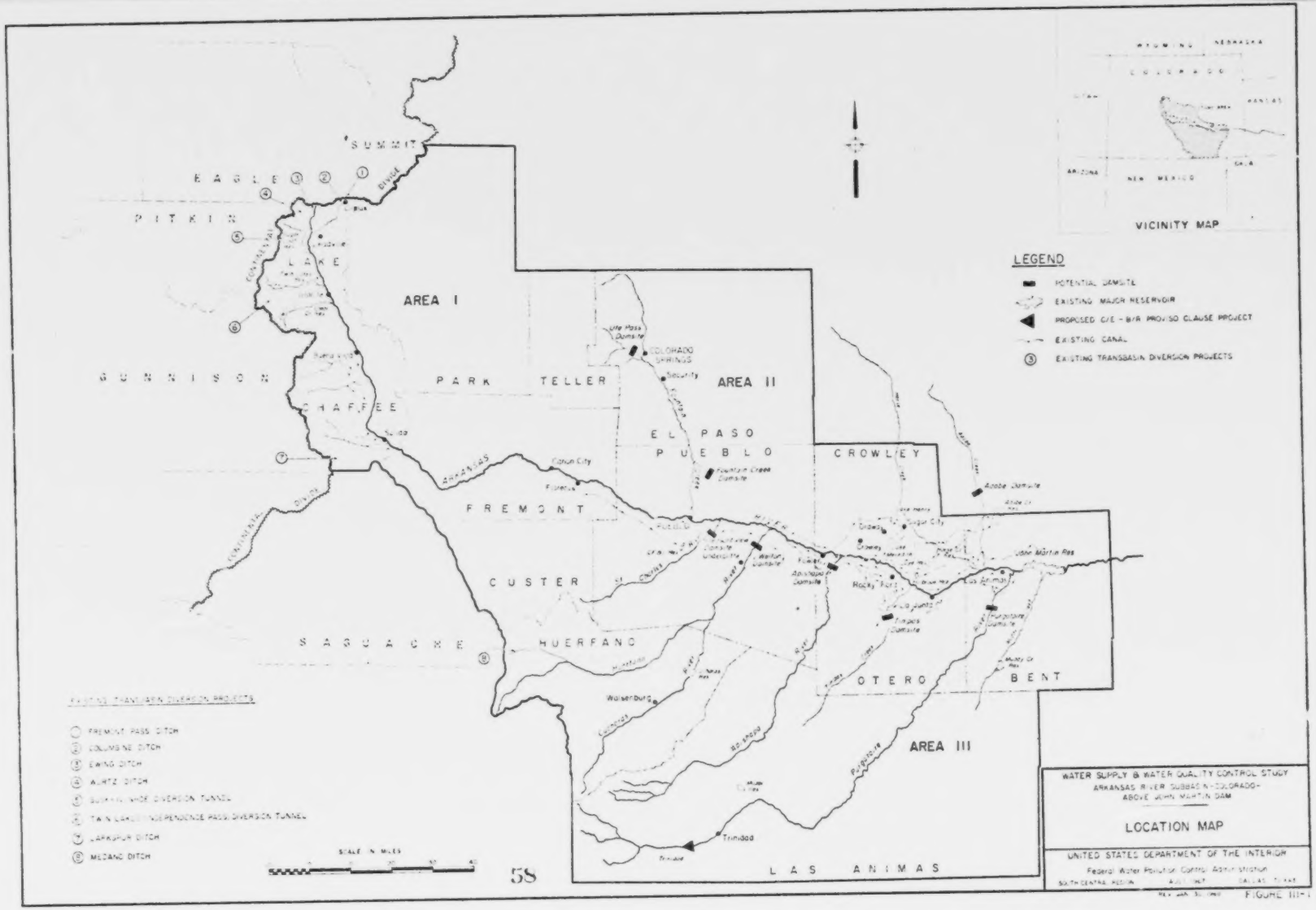


WATER SUPPLY & WATER QUALITY CONTROL STUDY
ARKANSAS RIVER SUBBASIN - COLORADO -
ABOVE JOHN MARTIN DAM

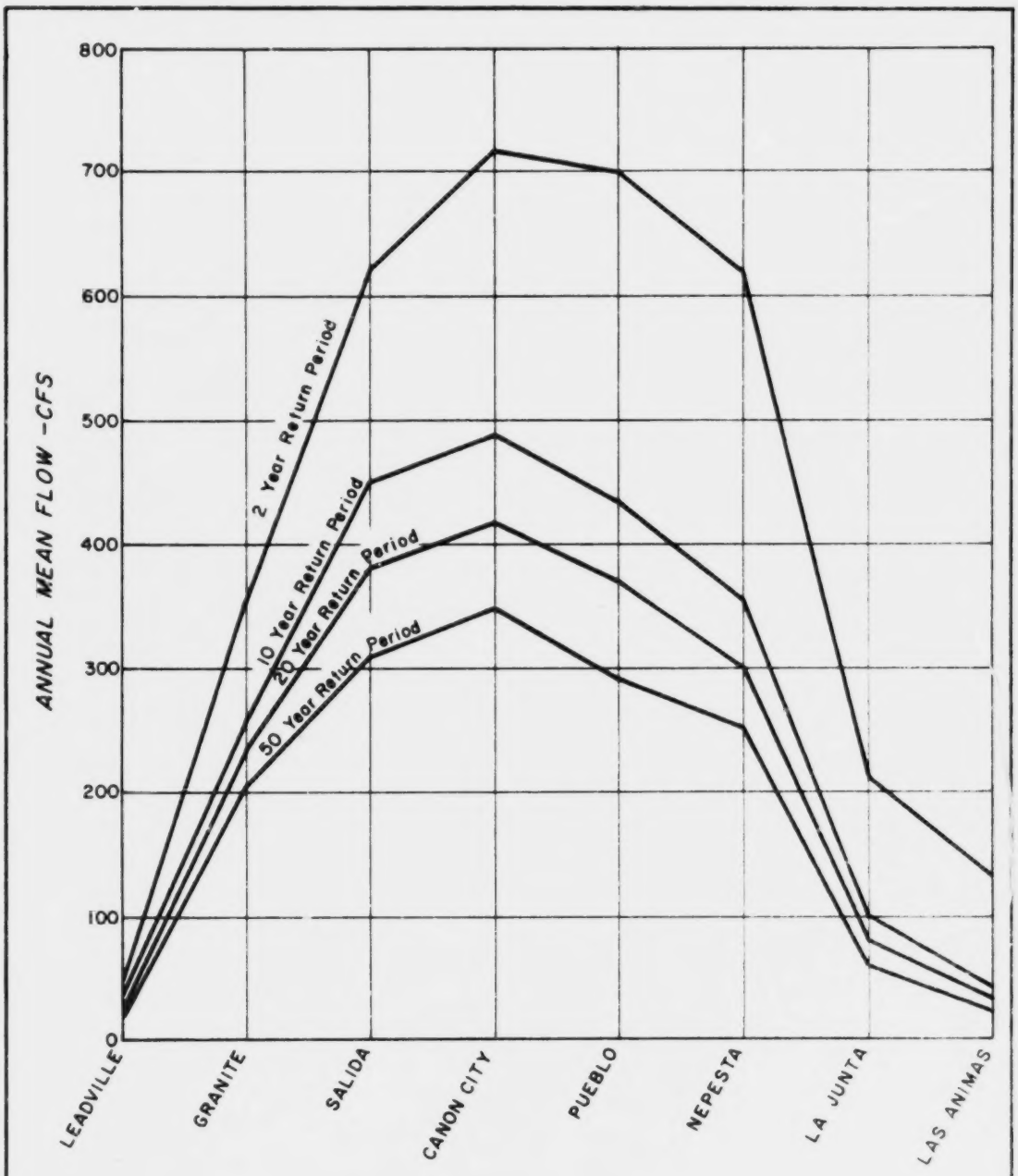
LOCATION MAP

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION — ALBUQUERQUE — DALLAS

FIGURE III-1

APPENDIX A

STREAMFLOW ANALYSIS



GAGING STATION	PERIOD OF RECORD
LEADVILLE*	OCT. 1910 – SEP. 1924
GRANITE	APR. 1910 – SEP. 1964
SALIDA	AUG. 1898 – SEP. 1899 APR. 1901 – OCT. 1903 OCT. 1909 – SEP. 1964
CANON CITY	JAN. 1888 – SEP. 1964
PUEBLO	JAN. 1886 – DEC. 1887 SEP. 1894 – SEP. 1964
NEPESTA	OCT. 1913 – SEP. 1964
LA JUNTA	APR. 1912 – SEP. 1964
LAS ANIMAS	MAY 1939 – SEP. 1964

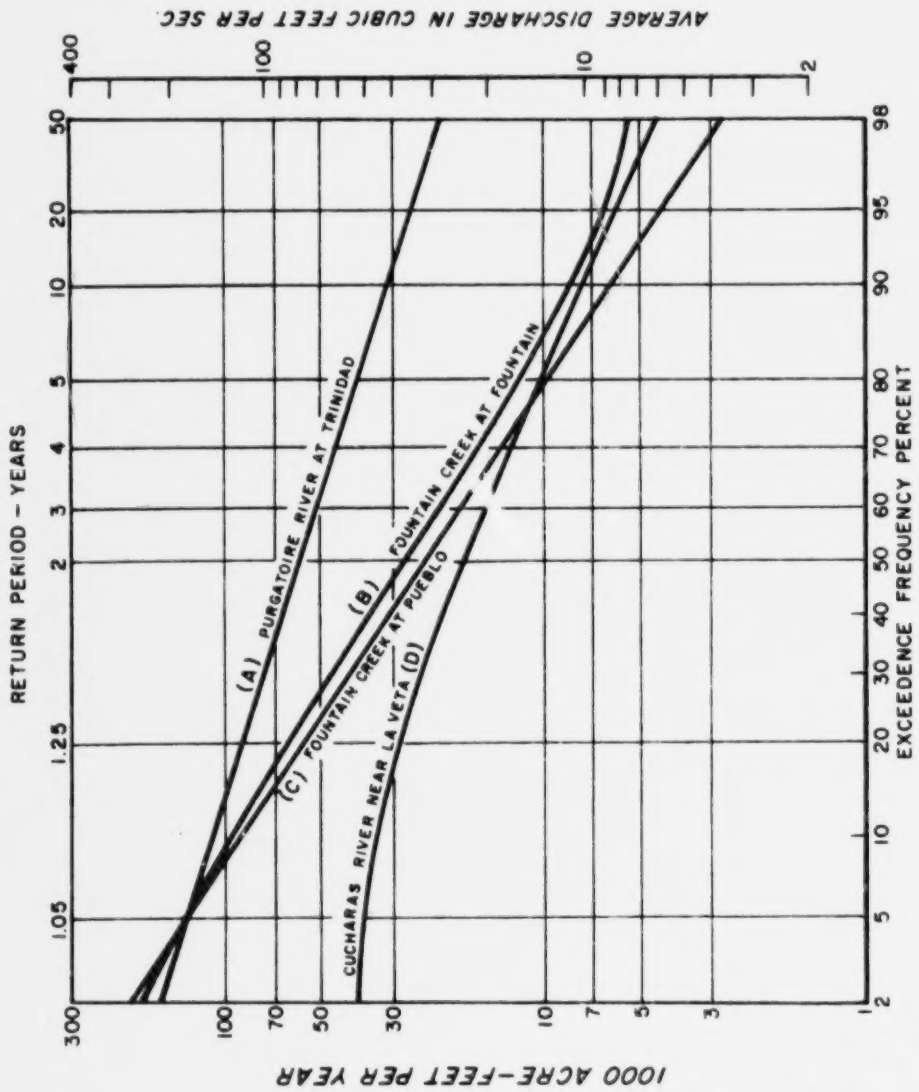
*EAST FORK ARKANSAS

WATER SUPPLY & WATER QUALITY CONTROL STUDY
ARKANSAS RIVER SUBBASIN-COLORADO--
ABOVE JOHN MARTIN DAM

STREAMFLOW ANALYSIS
MAINSTEM ARKANSAS RIVER
(PRESENT CONDITIONS)

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION JUN 1, 1966 DALLAS, TEXAS

FIGURE A-1



PERIOD OF RECORD

(A) OCT. 1885 – SEP. 1889
OCT. 1907 – NOV. 1908
SEP. 1909 – NOV. 1912
OCT. 1915 – SEP. 1960
OCT. 1962 – SEP. 1964

(B) OCT. 1938 – SEP. 1954

(C) JAN. 1922 – SEP. 1925
OCT. 1940 – SEP. 1964

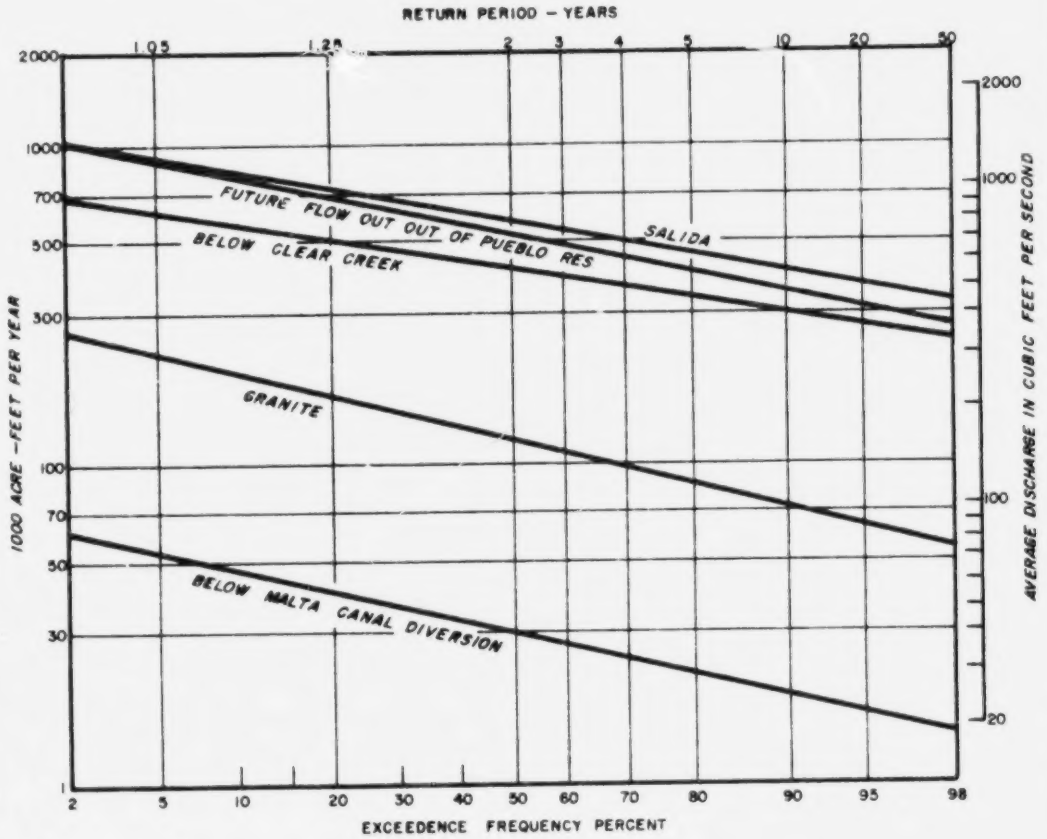
(D) OCT. 1934 – SEP. 1964

WATER SUPPLY & WATER QUALITY CONTROL STUDY
ARKANSAS RIVER SUBBASIN-COLORADO-
ABOVE JOHN MARTIN DAM

ANNUAL DISCHARGE FREQUENCY
SELECTED POINTS ON MAJOR TRIBUTARIES

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION JUN 1, 1966 DALLAS, TEXAS

FIGURE A-2



PERIOD OF RECORD

1928 – 1965

SOURCE: DATA FOR THIS ANALYSIS TAKEN FROM BUREAU OF RECLAMATION FRYINGPAN ARKANSAS PROJECT OPERATION STUDIES.

WATER SUPPLY & WATER QUALITY CONTROL STUDY
ARKANSAS RIVER SUBBASIN–COLORADO–
ABOVE JOHN MARTIN DAM

ANNUAL DISCHARGE FREQUENCY
MAINSTEM ARKANSAS RIVER
(FUTURE CONDITIONS)

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION AUG 1, 1966 DALLAS, TEXAS

FIGURE A–3

APPENDIX B

COST ANALYSES 28-31/

WATER QUALITY CONTROL BY FLOW REGULATION AND ADVANCED WASTE TREATMENT

Water Quality Control in the Arkansas River Below Pueblo

It has been assumed that direct releases to the river from Pueblo reservoir will decrease to zero by the year 2040 due to satisfaction of increasing municipal and industrial water demands from the reservoir and stream system above the reservoir. After 2030, flow in the river below Pueblo must be supplemented by controlled releases from reservoirs on tributary streams.

Method A - Storage for Flow Regulation

Construction Schedule

Reservoir	Year	Yield Needed (mgd)
Pleasant View	2030	12.6
Welton	2032	12.5
Apishapa	2034	21.5
Timpas	2038	17.9
Adobe	2055	11.6

Pleasant View Reservoir

Years use during study period	2030 - 2070
First Cost	$ 4,500,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 152,500
Annual operation and maintenance costs	22,500
Annual cost 100 yr. period	$ 175,000
Capitalize 40 years	$ 3,886,500
Discount 55 yr. (initial const. to 1970)	669,300
Amortize (100 yr. @ 3¼%)	22,700
Annual cost during study period	22,700

Welton Reservoir

Years use during study period	2032 - 2070
First Cost	$10,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 338,800
Annual operation and maintenance cost	50,000
Annual cost 100 yr. period	$ 388,800
Capitalize 38 years	$ 8,414,800
Discount 57 years (initial Const. to 1970)	1,359,300
Amortize (100 yr. @ 3¼%)	46,000
Annual cost during study period	$ 46,000

Apishapa Reservoir

Years use during study period	2034 - 2070
First Cost	$ 6,764,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 229,200
Annual operation and maintenance cost	33,800
Annual cost 100 yr. period	$ 263,000
Capitalize 36 years	$ 5,533,500
Discount 59 yr. (initial Const. to 1970)	838,500
Amortize (100 yr. @ 3¼%)	28,400
Annual cost during study period	28,400

Timpas Reservoir

Years use during study period	2038 - 2070
First Cost	$ 2,850,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 96,600
Annual operation and maintenance cost	14,300
Annual cost 100 year period	$ 110,900

Capitalize 32 years	$ 2,186,100
Discount 63 years (initial Constr. to 1990)	291,500
Amortize (100 yr. @ 3⅛%)	9,900
Annual cost during study period	$ 9,900

Adobe Reservoir

Years use during study period	2055 - 2070
First Cost	$ 4,400,000
Annual Cost:	
Amortize first cost (100 yr. @ 3⅛%)	$ 149,100
Annual operation and maintenance costs	22,000
Annual cost 100 year period	$ 171,100
Capitalize 15 years	$ 2,006,100
Discount 80 years (initial Constr. to 1970)	155,300
Amortize (100 yr. @ 3⅛%)	5,300
Annual cost during study period	$ 5,300

Summary of Annual Cost - Method A

Reservoir	Annual Cost
Pleasant View	$ 22,700
Welton	46,000
Apishapa	28,400
Timpas	9,900
Adobe	5,300
Total Annual Cost	$ 112,300

Method B - Storage for Flow Regulation and Advanced Waste Treatment

Use Pueblo, Pleasant View, and Welton Reservoirs for flow regulation with waste treatment facilities capable of 93 percent BOD removal.

Advanced waste treatment (coagulation-sedimentation) would not be required until the year 2030. Releases from Pueblo Reservoir would provide adequate flow for quality control to 2030.

Construction Schedule

Facilities	Year Needed
140 mgd coagulation-sedimentation waste treatment process	2030
Pleasant View Reservoir (12.6 mgd yield)	2035
25 mgd coagulation-sedimentation waste treatment process	2050
Welton Reservoir (6 mgd yield)	2060

2030 Facilities

Years use during study period	2030 - 2070
First Cost	$14,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 474,400
Annual operation and maintenance costs	823,400
Annual cost 100 yr. period	$ 1,297,800
Capitalize 40 years	$28,822,100
Discount 60 years	4,229,800
Amortize (100 yr. @ 3¼%)	143,300
Annual cost during study period	$ 143,300

2035 Facilities

Years use during study period	2035 - 2070
First Cost	$ 4,500,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 152,500
Annual operation and maintenance cost	22,500
Annual cost 100 yr. period	$ 175,000

Capitalize 35 years	$ 3,626,700
Discount 65 yr. (initial Constr. to 1970)	453,600
Amortize (100 yr. @ 3⅛%)	15,400
Annual cost during study period	$ 15,400

2050 Facilities

Years use during study period	2050 - 2070
First Cost	$ 2,500,000
Annual Cost:	
Amortize first cost (100 yr. @ 3⅛%)	$ 84,700
Annual operation and maintenance cost	147,000
Annual cost for 100 yr.	$ 231,700
Capitalize 20 years	$ 3,368,800
Discount 80 years	260,800
Amortize (100 yr. @ 3⅛%)	8,900
Annual cost during study period	$ 8,900

2060 Facilities

Years use during study period	2060 - 2070
First Cost	$ 6,000,000
Amortize first cost (100 yr. @ 3⅛%)	$ 203,300
Annual operation and maintenance cost	30,000
Annual cost 100 yr. period	$ 233,300
Capitalize 10 years	$ 1,964,900
Discount 90 yr. (initial Constr. to 1970)	110,500
Amortize (100 yr. @ 3⅛%)	3,700
Annual cost during study period	$ 3,700

Summary of Annual Cost - Method B

Facility	Year Needed	Annual Cost
140 mgd treatment	2030	$ 143,300
Pleasant View Reservoir	2035	15,400
25 mgd treatment	2050	8,900
Welton Reservoir	2060	3,700
Total Annual Cost		$ 171,300

Method C - Advanced Waste Treatment

Provide waste treatment facilities to increase BOD removal from 90 percent to 99 percent.

Advanced waste treatment (coagulation-sedimentation and adsorption) would not be required until the year 2030. Releases from Pueblo Reservoir would provide adequate flow for quality control to 2030.

Construction Schedule

Capacity Treatment Facilities (mgd)	Year Needed
140	2030
25	2050

2030 Facilities

Years use during study period	2030 - 2070
First Cost	$35,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 1,185,900
Annual operation and maintenance cost	1,547,400
Annual cost for 100 yr. period	$ 2,733,300
Capitalize 40 years	$60,702,300
Discount 60 years	8,908,400
Amortize (100 yr. @ 3¼%)	301,800
Annual cost for study period	$ 301,800

2050 Facilities

Years use during study period	2050 - 2070
First Cost	$ 6,250,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 211,800
Annual operation and maintenance cost	276,300
Annual cost 100 yr. period	$ 488,100

Capitalize 20 years	$ 7,096,700
Discount 80 years	549,400
Amortize (100 yr. @ 3½%)	18,600
Annual cost during study period	18,600

Summary of Annual Cost - Method C

Years Needed	Plant Size	Annual Cost
2030	140 mgd	$ 301,800
2050	25 mgd	18,600
		$ 320,400

COMPARISON OF COSTS[a/] FOR WATER QUALITY CONTROL[b/] IN THE ARKANSAS RIVER BELOW PUEBLO BY FLOW REGULATION AND ADVANCED WASTE TREATMENT

Method of Control		Annual Cost During Study Period
Method A		
Flow Regulation		
Pueblo Reservoir	1975 - 2030	
Pleasant View Reservoir	2030 - 2070	
Welton Reservoir	2032 - 2070	$112,300
Apishapa Reservoir	2034 - 2070	
Timpas Reservoir	2038 - 2070	
Adobe Reservoir	2055 - 2070	
Method B		
Advanced Waste Treatment		
90% BOD Removal	1970 - 2030	
93% BOD removal	2030 - 2070	
Flow Regulation		$171,300
Pueblo Reservoir	1975 - 2030	
Pleasant View Reservoir	2035 - 2070	
Welton Reservoir	2060 - 2070	
Method C		
Advanced Waste Treatment		
90% BOD Removal	1970 - 2030	
99% BOD Removal	2030 - 2070	$320,400
Flow Regulation		
Pueblo Reservoir	1975 - 2030	

a/ Does not include cost to provide primary and secondary treatment facilities for first 90 percent BOD removal.

b/ Maintenance of a minimum of 4.0 mg/l dissolved oxygen.

Water Quality Control in Fountain Creek

Two reservoirs, Ute Pass and Fountain Creek could be used to provide storage for supplementing streamflow in Fountain Creek. However, even with supplemental flow from these reservoirs, waste treatment would be required for 90 percent BOD removal from 1970 to 2010, 93 percent BOD removal from 2010 to 2060, and 99 percent removal from 2060 to 2070. Computations below compare cost of storage with costs of additional facilities required if storage is not provided. Total costs for waste disposal have not been computed.

Method A - Storage for Flow Regulation

Ute Pass Reservoir

Years use during study period	1970 - 2070
Yield	26.9 mgd
First Cost	$13,000,000
Annual Cost:	
Amortize first cost (100 yrs.@ 3¼%)	$ 440,500
Annual operation and maintenance	65,000
Annual cost for study period	$ 505,500

Fountain Creek Reservoir

Years use during study period	1990 - 2070
Yield	14.1 mgd
First Cost	$26,600,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 901,300
Annual operation and maintenance	133,000
Annual cost for 100 year period	$ 1,034,300
Capitalize 80 years	$29,361,100
Discount 15 years (initial Constr. to 1970)	18,172,800
Amortize (100 yr. @ 3¼%)	615,800
Annual cost for study period	$ 615,800

Summary of Annual Cost - Method A

Ute Pass	$ 505,500
Fountain Creek	615,800
Total Annual Cost	$ 1,121,300

Method - B

Provide waste treatment facilities for 99 percent BOD removal.

With supplemental flows provided by Ute Pass and Fountain Creek Reservoirs or by pumping water from the Arkansas River, waste treatment would be required for 90 percent BOD removal from 1970 to 2010, 93 percent BOD removal from 2010 to 2060, and 99 percent removal from 2060 to 2070. Without the supplemental flows, waste treatment facilities for 99 percent BOD removal would be required for the entire study period. The cost of increasing the degree of waste treatment can be considered an alternative to providing quality control storage.

-Increase From 90 to 99 Percent BOD removal-

1970 (Add 70 mgd coagulation-sedimentation process)

Years use during study period	1970 - 2070
Capital Cost	$ 7,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 237,200
Annual operation and maintenance	411,700
Annual cost during study period	$ 648,900

1970 (Add 70 mgd adsorption process)

Years use during study period	1970 - 2070
Capital Cost	$10,500,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 355,800
Annual operation and maintenance	362,000
Annual cost during study period	$ 717,800

1990 (Add additional 30 mgd coagulation-sedimentation process)

Years use during study period	1990 - 2070
Capital Cost	$ 3,000,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	$ 101,700
Annual operation and maintenance	176,400
Annual cost for 100 year period	$ 278,100
Capitalize 80 years	$ 7,894,500
Discount 20 years	4,164,100
Amortize (100 yr. @ 3½%)	141,100
Annual cost during study period	$ 141,100

1990 (Add additional 30 mgd adsorption process)

Years use during study period	1990 - 2070
Capital Cost	$ 4,500,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	$ 152,500
Annual operation and maintenance	155,200
Annual cost 100 year period	$ 307,700
Capitalize 80 years	$ 8,734,800
Discount 20 years	4,607,400
Amortize (100 yr. @ 3½%)	156,100
Annual cost during study period	$ 156,100

-Increase From 93 to 99 Percent BOD Removal-

2010 (Add additional 40 mgd adsorption process)

Years use during study period	2010 - 2070
Capital Cost	$ 6,000,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	$ 203,300
Annual operation and maintenance	206,900
Annual cost 100 year period	$ 410,200
Capitalize 60 years	$10,769,200
Discount 40 years	2,996,300
Amortize (100 yrs. @ 3½%)	101,500
Annual cost during study period	$ 101,500

2030 (Add additional 40 mgd adsorption process)

Years use during study period	2030 - 2070
Capital Cost	$ 6,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 203,300
Annual operation and maintenance	206,900
Annual cost 100 year period	$ 410,200
Capitalize 40 years	$ 9,109,900
Discount 60 years	1,336,900
Amortize (100 yr. @ 3¼%)	45,300
Annual cost during study period	$ 45,300

2050 (Add additional 25 mgd adsorption process)

Years use during study period	2050 - 2070
Capital Cost	$ 3,750,000
Annual Cost:	
Amortize first cost (100 yrs. @ 3¼%)	$ 127,000
Annual operation and maintenance	129,300
Annual cost 100 year period	$ 256,300
Capitalize 20 years	$ 3,726,400
Discount 80 years	288,500
Amortize (100 yr. @ 3¼%)	9,800
Annual cost during study period	$ 9,800

Summary of Annual Cost - Method B

1970 facilities	$ 1,366,700
1990 facilities	297,200
2010 facilities	101,500
2030 facilities	45,300
2050 facilities	9,800
Total Annual Cost	$ 1,820,500

Discussion

Costs for land disposal of wastes are also presented in this appendix. If waste is discharged to land rather than Fountain Creek, treatment for only 90 percent BOD removal would be adequate for the entire study period. If control methods above are compared to land disposal, it is necessary to determine the cost of increasing the degree of waste treatment from 90 percent to the levels assumed in the above analyses. This cost added to costs determined above, will be comparative with control methods requiring only 90 percent waste treatment.

-Increase From 90 to 93 Percent BOD Removal-

2010 (Add 140 mgd coagulation-sedimentation process)

Capital Cost	$14,000,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	$ 474,400
Annual operation and maintenance cost	823,400
Annual cost for 100 year period	$ 1,297,800
Capitalize 60 years	$34,072,000
Discount 40 years	9,481,100
Amortize (100 yrs. @ 3½%)	321,300
Annual cost during study period	$ 321,300

-Increase From 93 to 99 Percent Removal-

2060 (Add 88 mgd coagulation -sedimentation process)

Capital Cost:	$ 8,800,000
Annual Cost:	
Amortize first cost (100 yr. @ 3½%)	$ 298,200
Annual operation and maintenance cost	517,600
Annual cost for 100 year period	$ 815,800
Capitalize 10 years	$ 6,871,000
Discount 90 years	386,300
Amortize (100 yrs. @ 3½%)	13,100
Annual cost during study period	$ 13,100

2060 (Add 88 mgd adsorption process)

Capital Cost:	$13,200,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 447,300
Annual operation and maintenance cost	455,200
Annual cost for 100 year period	$ 902,500
Capitalize 10 years	$ 7,601,200
Discount 90 years	427,300
Amortize (100 yrs. @ 3¼%)	14,500
Annual cost during study period	$ 14,500

Summary of Annual Costs:

2010 facilities	$ 321,300
2060 facilities	27,600
	$ 348,900

Table B-2

COMPARISON OF COSTS[a/]
FOR
WATER QUALITY CONTROL[b/] IN FOUNTAIN CREEK BY
FLOW REGULATION AND ADVANCED WASTE TREATMENT

Method of Control		Annual Cost During Study Period
Method A		
Advanced Waste Treatment		
90% BOD Removal	1970 - 2010	
93% BOD Removal	2010 - 2060	
99% BOD Removal	2060 - 2070	
(Flow exceeding 140 mgd)		$ 1,470,200
Supplemental Flows		
Ute Pass Reservoir	1970 - 2070	
Fountain Creek Reservoir	1990 - 2070	
Method B		
Advanced Waste Treatment		
99% BOD Removal	1970 - 2070	$ 2,169,400

a/ Does not include cost to provide primary and secondary treatment facilities for first 90 percent BOD removal.

b/ Maintenance of a minimum of 4.0 mg/l dissolved oxygen.

WATER QUALITY CONTROL BY LAND DISPOSAL OF WASTES[21-23/]

Through the year 2020, waste produced at Colorado Springs can be transported by pipeline to the vicinity of Pueblo re-aerated to restore the dissolved oxygen concentration to 4 mg/l and discharged to the Arkansas River. Releases from Pueblo Reservoir will be adequate to dilute these wastes and all other wastes to be discharged to the river below the reservoir. However, it has been assumed that releases from Pueblo Reservoir will be reduced to zero by the year 2040 due to increasing uses of water in and above the reservoir for water supplies. After the year 2020 wastes from Colorado Springs and Pueblo can no longer be discharged to the river unless the flow is supplemented. Facilities were designed to transport wastes from

these cities directly to farming areas for irrigation. Only major transmission pipelines were designed with the assumption that distribution to individual farms would be the responsibility of farm owners. (See figure B-1)

Design Criteria:

Use oxygen transfer rates at 23°C
Maintain D.O. in pipelines above 1.0 mg/l
Maintain D.O. above 4.0 mg/l where waste is discharged to the stream system
Maintain 4.0 mg/l D.O. in waste treatment plant effluents
Provide waste treatment plants capable of removing 90 percent of the BOD load
Detention in Aeration Basins - 2 hours

Pipeline Capacity: (See figure B-1)

Pipeline Diameter (inches)	Capacity (mgd)	Velocity (fps)
72	120	4
72	115	3.8
66	90	3.8
66	80	3.4
60	60	3.4
36	55	3.4
30	35	3.4

Aeration Basin Capacity: (See figure B-1)

Basin	Size LXWXD (feet)	No. Surface Aerators	Aerator Rotor Horsepower	Flow (mgd)
A	291X291X10	9	6.8	75
B	291X194X10	6	6.8	50
C	291X291X10	9	6.8	75
D	258X248X10	9	4.6	60
E	291X291X10	9	6.8	75
F	258X258X10	9	4.6	60
G	291X194X10	6	6.8	50
H	258X86X10	3	4.6	20
I	291X194X10	6	6.8	50
J	258X86X10	3	4.6	20

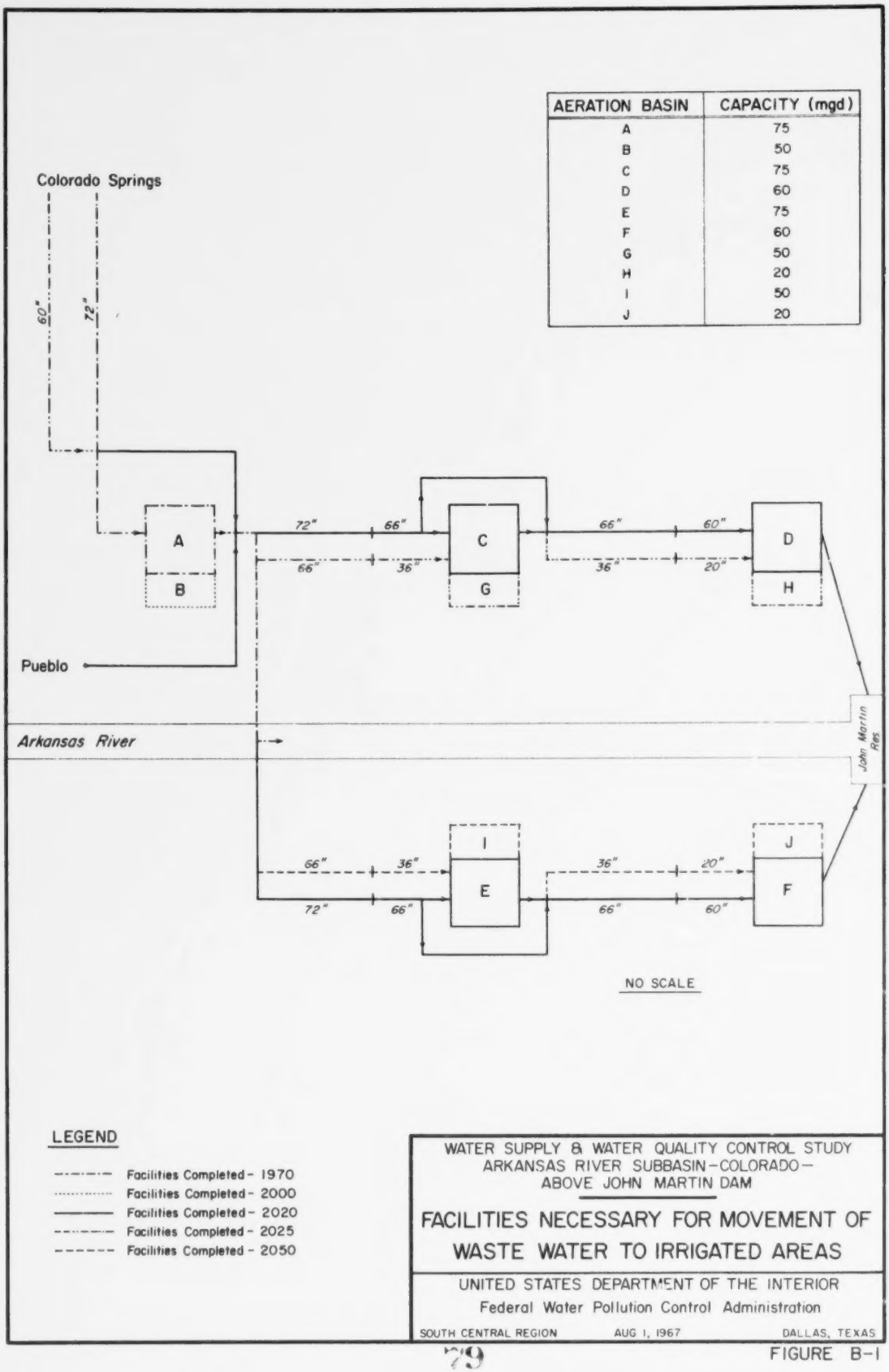

AERATION BASIN | CAPACITY (mgd)
A 75
B 50
C 75
D 60
E 75
F 60
G 50
H 20
I 50
J 20
Colorado Springs
60"
72"
A
B
72"
66"
C
66"
36"
G
66"
60"
D
36"
20"
H
Pueblo
Arkansas River
John Martin Res
I
J
66"
36"
E
36"
20"
F
72"
66"
66"
60"
NO SCALE
LEGEND
Facilities Completed - 1970
Facilities Completed - 2000
Facilities Completed - 2020
Facilities Completed - 2025
Facilities Completed - 2050
WATER SUPPLY & WATER QUALITY CONTROL STUDY
ARKANSAS RIVER SUBBASIN - COLORADO -
ABOVE JOHN MARTIN DAM
FACILITIES NECESSARY FOR MOVEMENT OF
WASTE WATER TO IRRIGATED AREAS
UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION
AUG 1, 1967
DALLAS, TEXAS

FIGURE B-1

1970 Facilities

Years use during study period	1970 - 2070
First Cost:	
45 miles of 72 inch pipeline	$18,000,000
Aeration Basin A	11,250,000
	$29,250,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 991,100
Annual operation and maintenance costs	150,000
Annual cost for study period	$ 1,141,100

2000 Facilities

Years use during study period	2000 - 2070
First Cost:	
Aeration basin B	$ 7,500,000
Annual Cost:	
Amortize first cost (100 yr. @ 3¼%)	$ 254,100
Annual operation and maintenance cost	100,000
Annual cost for 100 year period	$ 354,100
Capitalize 70 years	$ 9,734,100
Discount 30 years	3,729,000
Amortize (100 yr. @ 3¼%)	126,400
Annual cost during study period	$ 126,400

2020 Facilities

Years use during study period	2020 - 2070
First Cost:	
60 miles of 72 inch pipeline	$24,000,000
80 miles of 66 inch pipeline	28,000,000
20 miles of 60 inch pipeline	5,900,000
Aeration basin C	11,250,000
Aeration basin D	9,000,000
Aeration basin E	11,250,000
Aeration basin F	9,000,000
	$98,400,000

Annual Cost:

Amortize first cost (100 yr. @ 3⅛%)	$ 3,334,100
Annual operation and manintenance	540,000
Annual cost for 100 year period	$ 3,874,100
Capitalize 50 years	$95,116,000
Discount 50 years	19,219,900
Amortize (100 yr. @ 3⅛%)	651,200
Annual cost during study period	$ 651,200

2025 Facilities

Years use during study period	2025 - 2070

First Cost:

30 miles of 66 inch pipeline	$10,500,000
45 miles of 60 inch pipeline	13,275,000
40 miles of 36 inch pipeline	5,120,000
10 miles of 30 inch pipeline	1,030,000
Aeration basin G	7,500,000
Aeration basin H	3,000,000
	$40,425,000

Annual Cost:

Amortize first cost (100 yr. @ 3⅛%)	$ 1,369,700
Annual operation and maintenance cost	140,000
Annual cost for 100 year period	$ 1,509,700
Capitalize 45 years	$35,438,100
Discount 55 years	6,102,600
Amortize (100 yr. @ 3⅛%)	206,800
Annual cost during study period	$ 206,800

2050 Facilities

Years use during study period	2050 - 2070

First Cost:

30 miles 66 inch pipeline	$10,500,000
40 miles 36 inch pipeline	5,120,000
10 miles 30 inch pipeline	1,030,000
Aeration basin I	7,500,000
Aeration basin J	3,000,000
	$27,150,000

Annual Cost:

Amortize first cost (100 yr. @ 3½%)	$ 919,900
Annual operation and maintenance cost	140,000
Annual cost for 100 year period	$ 1,059,900
Capitalize 20 years	$15,410,300
Discount 80 years	1,192,900
Amortize (100 yr. @ 3½%)	40,420
Annual cost during study period	$ 40,420

Summary of Annual Costs:

1970 facilities	$ 1,141,100
2000 facilities	126,400
2020 facilities	651,200
2025 facilities	206,300
2050 facilities	40,400
	$ 2,165,900

COMPARISON OF COSTS[a] FOR WATER QUALITY CONTROL[b] IN THE STUDY AREA

Method of Control		Annual Cost During Study Period (1970-2070)
Flow Regulation and Advanced Waste Treatment		
Fountain Creek (Method A)[c]	$ 1,470,200	$1,582,500
Ark. River below Pueblo (Method A)[d]	112,300	
Land Disposal		$2,165,900
Advanced Waste Treatment		
Fountain Creek (Method B)[c]	$ 2,169,400	$2,489,800
Ark. River below Pueblo (Method C)[d]	320,400	

a/ Does not include cost to provide primary and secondary treatment facilities for first 90 percent BOD removal.

b/ Maintenance of a minimum of 4.0 mg/l dissolved oxygen.

c/ From Table B-2

d/ From Table B-1